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GEOLOGY OF BARIUM, STRONTIUM, AND FLUORINE DEPOSITS IN CANADA

K.R. DAWSON

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Preface

Barium, strontium and fluorine have many industrial applications. All have been produced in Canada during this century but at present our needs for strontium chemicals, crude fluorite and fluorine chemicals are met by imports, mainly from Mexico and the United States.

Barite is primarily employed in the heavy drilling muds used in the petroleum exploration industry. It is also used as a filler in a variety of products and an additive in glass and ceramics. Strontium, which is derived from the mineral celestite, is used to produce a variety of chemicals that have extensive applications in the glass, ceramic, metallurgical, pyrotechic and pharmaceutical industries. Several strontium compounds when ignited produce the brilliant crimson flame common in fireworks, safety flares and tracer ammunition. Fluorite is used mainly to manufacture hydrogen fluoride which has many industrial uses. Inorganic fluorides are used in insecticides, in preservatives, antiseptics and in toothpaste.

In this report the geochemistry and mineralogy of the three elements are described as a background to the main purpose of the publication, a description of the geology of the 733 known Canadian occurrences of barium, strontium and fluorine.

This study suggests that our resources of the three elements are sufficient for domestic requirements and that in the case of barium and strontium exports could be considered. The world market for barite is closely related to oil exploration activity and because of the bulky nature of the product, sources of supply near the centres of activity will be most competitive. However substitutes for barite in drilling muds could threaten the entire market. The use of strontium compounds in the electronics field is increasing but known world resources appear more than adequate to meet expected demand. World demand for fluorite has been closely tied to the chemical, steel and alumimun industries. In the case of the latter two, changing technologies suggest that markets lost during the recent economic recession may not be easily regained. Fluorine chemicals also have an important application in the nuclear fuel industry and the long-term future of nuclear-powered electrical generating plants will be important to the exploitation of Canada's fluorite deposits.

R.A. Price
Director General
Geological Survey of Canada

Préface

Le baryum, le strontium et le fluor connaissent de nombreuses utilisations industrielles. Le Canada en a produit tout au long du siècle mais il doit actuellement en importer, principalement du Mexique et des États-Unis, pour subvenir à ses besoins de dérivés chimiques de strontium et de fluorine, ainsi que de fluor brut.

La barytine est surtout utilisée par l'industrie d'exploration pétrolière, dans les boues de forage lourdes. De plus, elle sert de charge dans la fabrication de divers produits et d'additif pour la fabrication du verre et de la céramique. Par ailleurs, le strontium, dérivé du minéral célestine, sert à obtenir divers produits chimiques d'utilisation courante dans l'industrie du verre et de la céramique, en métallurgie, en pyrotechnie et en pharmacie. Lorsqu'ils s'enflamment, plusieurs composés du strontium produisent cette flamme rouge si lumineuse qui caractérise les feux d'artifice, les fusées de sécurité et les munitions traçantes. La fluorine, elle, sert à produire le fluorure d'hydrogène que l'on retrouve dans de nombreux produits, sous forme inorganique, comme les insectisides, les agents de préservation, les antiseptiques et les dentifrices.

Le présent rapport décrit la géochimie et la minéralogie des trois éléments dans le but exprès de mieux faire comprendre au lecteur la géologie des 733 gîtes dont l'existence est connue au Canada.

D'après les résultats de l'étude, les ressources canadiennes de ces trois éléments suffisent aux besoins intérieurs et, dans le cas du baryum et du strontium, laissent présager des possibilités d'excédents exportables. Comme le marché mondial de la barytine est largement tributaire de l'exploration pétrolière et étant donné la nature massive de ce produit, il serait nettement préférable d'en trouver des sources près des centres de consommation. Les substituts utilisés dans les boues de forage pourraient cependant mettre en danger le marché tout entier. L'électronique fait de plus en plus appel aux composés du strontium; les réserves mondiales connues semblent toutefois dépasser la demande prévue. De même, la demande mondiale de fluorine dépend largement des besoins des industries de produits chimiques, de l'acier et de l'aluminium. Étant donné les percées technologiques survenues dans les deux dernières, les marchés perdus durant la récente récession pourraient s'avérer fort difficiles à récupérer. Les dérivés chimiques du fluor sont aussi largement utilisés dans l'industrie des combustibles nucléaires. Il va sans dire que les perspectives à long terme des centrales nucléaires détermineront dans une grande mesure l'échelle d'exploitation des dépôts de fluorine au Canada.

Le directeur général de la
Commission géologique du Canada
R.A. Price

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GEOLOGY OF BARIUM, STRONTIUM, AND FLUORINE DEPOSITS IN CANADA

Abstract

In this report the geochemistry and minealogy of barium, strontium and fluorine are described, occurrences are delineated and areas and geological conditions favouruble for additional occurrences are indicated. The relationships of the three elements to one another as well as to other metallic and nonmetallic elements in Canada are emphasized.

Much of the report is devoted to a description of deposits in terms of origin. Deposits of each of the three elements are broadly grouped as syngenetic or epigenetic and further grouped as deposits in igenous rocks, in clastic sediments, chemical sediments, fissure fillings and replacement deposits. Although emphasis is given to Canadian deposits others are described to better elucidate the formation of Canadian deposits. The report includes comprehensive tables listing all Canadian occurrences, the major elements found in them and their developmental status, and a complete geographic listing. A total of 733 localities are plotted on a 1:5 million geological map of Canada to illustrate the geographical distribution and geological environments of deposits containing one or more of the three element.

The report concludes with descriptions of the geological associations of Ba, Sr and F including their geochemistry and structural environments, descriptions of prospecting methods and an assessment of Canadian resources in relation to world supply.

Résumé

Le présent rapport donne la description de la géochimie et de la minéralogie du baryum, du strontium et du fluor, une délimitation des venues et une indication des régions et des conditions géologiques favorables à la découverte d'autres gîtes. L'accent est mis sur les rapports qui existent entre les trois éléments et sur ceux qui les unissent à d'autres éléments, métalliques ou non, au Canada.

Le rapport est consacré en grande partie à la description des dépôts selon leurs origines. Les gîtes de chaque élément sont d'abord classés comme syngénétiques ou épigénétiques; ils sont ensuite davantage groupés (roches ignées, sédiments clastiques, sédiments chimiques, remplissages de crevasses, gîtes de substitution). Bien que l'on insiste sur les gîtes canadiens, d'autres dépôts sont également décrits afin de mieux expliquer la formation des gisements canadiens. Le rapport comprend des tableaux détaillés qui énumèrent tous les gisements canadiens, les principaux éléments qu'ils contiennent et leur état d'évolution, ainsi qu'une liste complète de leurs emplacements. Au total, 733 localités sont répertoriées sur une carte géologique du Canada, dressée à 1/5 000 000, qui illustre la répartition géographique et les milieux géologiques des dépôts renfermant au moins un des trois éléments.

En conclusion, le rapport offre une description des associations géologiques de Ba, de Sr et de F, y compris leur géochimie et la formation qui les renferme; il détaille par ailleurs les méthodes de prospection et évalue les ressources canadiennes par rapport aux approvisionnements mondiaux.

SUMMARY

DISTRIBUTION

Deposits and occurrences of Ba, Sr, and F minerals are widespread across Canada. Map 1588A illustrates the geographical distribution and geological environment of 733 localities at which one or more of the three elements occur. Geographically most occurrences are in Ontario, British Columbia, Yukon, Nova Scotia and Newfoundland; there are only a few occurrences in the other provinces, with the fewest being in Saskatchewan and the Northwest Territories.

In this study, 733 deposits and occurrences have been catalogued and of these 444 are barium-bearing, 37 are strontium-bearing, and 336 are fluorine-bearing. Individual occurrences commonly contain more than one of the three elements and this results in the anomalous total (817). A total of 190 localities have reported production: of these, 40 produced barium, 8 produced strontium and 48 produced fluorine and the remaining 84 produced sulphide ores that contained one or more of the three elements in gangue minerals. The last group includes several producers and past producers that are potential future sources of barium (and less probably fluorine) from abandoned tailings ponds. Resources of the three elements appear to be sufficient for Canada's domestic requirements and to provide a surplus for export, particularly in the case of barium and strontium.

GEOLOGICAL ASSOCIATIONS

Ba, Sr and F occur in several geological provinces of Canada, including the Cordilleran Orogen, the Bear, Slave, Churchill, Superior and Southern provinces of the Canadian Shield, and the Appalachian Orogen of Eastern Canada. Occurrences in the Cordillera are particularly numerous near Macmillan Pass, Yukon Territory along the southwest margin of the Mackenzie Fold Belt; in the Cassiar Belt near the Yukon-British Columbia border; the Rocky Mountain Thrust Belt near Muncho Lake in the Coast Plutonic Belt; Bowser Basin; Columbia Intermontane Belt near Alice Arm; in the Insular Fold Belt on Vancouver Island; in the Purcell Anticlinorium and in the Omineca Crystalline Belt near the International Boundary. These occurrences are in rocks affected by the Laramide, Columbian and Nassian orogenies and less commonly in rocks imprinted by Inklinian and Tahltanian disturbances.

Cordilleran Orogen

Barite production from the Cordilleran Orogen is typically from veins and from tailings of abandoned base metal mines. The barite-rich tailings were produced from base metal veins and replacement deposits in the rocks of the Purcell Anticlinorium near the International Boundary. In the future, barite may be recovered from mine tailings near the boundary of the Intermontane Volcanic Belt and the Coast Plutonic Belt, near Alice Arm and in the Insular Fold Belt on Vancouver Island and from baritites interbedded with argillites and limestones in Yukon Territory and northeastern British Columbia. Celestite has not been produced from the Cordillera although it occurs in minor to trace amounts on several properties. Approximately 30 000 tonnes of fluorite was mined at the Rock Candy mine north of Grand Forks, near the United States border between 1918 and 1925. Fluorite reserves amounting to 500 000 tonnes 36.7% CaF_2 have been proven on the Tam prospect of Liard Fluorite Mines Ltd., north of the Liard Bridge on the Alaska Highway near Mile 497. Elsewhere in the Cordillera other potential sources of supply may be in tailings of such mines as the abandoned Highland Mine and Kootenay Florence Mine in southern British Columbia.

Bear, Slave and Churchill Provinces

A few Ba, Sr and F occurrences are present in the Bear, Slave and Churchill provinces in the northwest part of the Precambrian Shield, in rocks deformed during the Kenoran and Hudsonian orogenies. Most known occurrences are near Port Radium and Coppermine River in Bear Province and in the East Arm Fold Belt and Nueltin Lake areas of Churchill Province.

SOMMAIRE

RÉPARTITION

Les gisements et venues de Ba, de Sr et de F se retrouvent un peu partout au Canada. La carte 1588A donne la répartition géographique et le milieu géologique de 733 emplacements où l'on retrouve un ou plusieurs de ces trois éléments. En termes de géographie, la plupart des venues se situent en Ontario, en Colombie-Britannique, au Yukon, en Nouvelle-Écosse et à Terre-Neuve; elles sont peu nombreuses dans les autres provinces, plus particulièrement en Saskatchewan et dans les Territoires du Nord-Ouest.

Dans la présente étude, on a catalogué 733 gisements et venues dont 444 contiennent du baryum, 37 du strontium et 336 du fluor. Dans plusieurs cas, on y retrouve plus d'un des éléments, ce qui explique la somme anormale de 817. Des 190 emplacements exploités, 40 produisent du baryum, 8 du strontium, 48 du fluor et les 84 qui restent, des minerais sulfurés contenant un ou plusieurs des trois éléments dans des minéraux de gangue. Ce dernier groupe comprend plusieurs mines actuelles et anciennes desquelles on pourra éventuellement tirer du baryum (et moins vraisemblablement du fluor) des bassins de résidus abandonnés. L'ampleur des ressources semble suffisante pour répondre aux besoins nationaux et pour fournir des excédents en vue de l'exportation, plus particulièrement dans le cas du baryum et du strontium.

ASSOCIATIONS GÉOLOGIQUES

Le Ba, le Sr et le F se manifestent dans plusieurs provinces géologiques du Canada, y compris dans l'orogène de la Cordillère, les provinces de l'Ours, des Esclaves, de Churchill, du lac Supérieur et du Sud dans le Bouclier canadien ainsi que dans l'orogène des Appalaches situé dans l'Est du pays. Dans l'orogène de la Cordillère, les venues sont particulièrement nombreuses près du col Macmillan, au Yukon, le long de la limite sud-ouest de la zone de plissements de Mackenzie; dans la zone des Cassiars, près de la limite entre le Yukon et la Colombie-Britannique; dans la zone de chevauchements des Rocheuses, près de Muncho Lake dans la zone plutonique côtière; dans le bassin de Bowser; dans la zone d'entremonts de Columbia près d'Alice Arm; dans la zone insulaire de plissements de l'île Vancouver; dans l'anticlinorium de Purcell et dans la zone cristalline d'Ominéca, près de la frontière internationale. Les venues gisent dans des roches touchées par les orogénèses du Laramide, du Columbien et du Nassien et, plus rarement, dans des roches marquées par des accidents survenues en cours de l'Inklinien et du Tahltanien.

Orogène de la Cordillère

Dans l'orogène de la Cordillère, la baryte est habituellement tirée de filons et des résidus de mines de métaux communs abandonnées. Les résidus riches en baryte proviennent des veines de métaux communs et des gisements de substitution dans des roches de l'anticlinorium de Purcell, près de la frontière avec les États-Unis. Il se peut qu'à l'avenir on récupère la baryte des résidus des mines situées près de la limite entre la zone volcanique d'entremonts et la zone plutonique côtière, près d'Alice Arm et dans la zone insulaire de plissements de l'île Vancouver ainsi que des barytines intercalées dans de l'argilite et du calcaire dans le territoire du Yukon et le nord-est de la Colombie-Britannique. On n'a pas encore extrait de célestine de cet orogène, bien que plusieurs propriétés en contiennent dans des quantités dont l'importance varie de mineure à infinitésimale. Entre 1918 et 1925, la mine Rock Candy, au nord de Grand Forks, près de la frontière avec les États-Unis, a produit environ 30 000 t de fluorine. De plus, on a prouvé que la concession Tam de la Liard Fluorite Mines Ltd., située au nord du pont Liard, près de la borne miliaire 497 de la route de l'Alaska, contenait des réserves de fluorine de l'ordre de 500 000 t de minerai à teneur de 36,7 % en CaF_2. Ailleurs dans l'orogène, les autres sources possibles pourraient être les résidus de mines abandonnées comme celles de Highland et de Kootenay Florence, dans le sud de la Colombie-Britannique.

Provinces de l'Ours, des Esclaves et de Churchill

Il y a quelques venues de Ba, de Sr et de F dans les provinces de l'Ours, des Esclaves et de Churchill, situées dans la partie nord-ouest du Bouclier précambrien; elles se manifestent dans des roches déformées durant les orogénèses du Kénoranien et de l'Hudsonien. La plupart des venues connues se situent près de Port Radium et de Coppermine River, dans la province de l'Ours et dans la zone de plissements d'East Arm et la région de Neultin Lake, dans la province de Churchill.

Superior Province

The Superior Province contains a number of barium and fluorine deposits and occurrences. Barium production has been limited to the mining of a few small barite veins in the Abitibi volcanic belt. Fluorite has not been produced from the Superior Province although minor amounts occur in pegmatite dykes at the boundary between the Uchi Volcanic Belt and English River Gneiss Belt in the Bird River District of Manitoba. Fluorite also occurs with molybdenite near the Lacorne Batholith in the Québec part of the Abitibi volcanic belt.

Southern Province

The Southern Province contains many barite deposits and occurrences, mainly in the Penokean Fold Belt of Thunder Bay District and in the Cobalt Embayment. Barite veins have been mined in Thunder Bay District and the mineral is also commonly present as a gangue in silver-bearing and base metal veins of the district. The latter are usually associated with Keweenawan diabase dykes and sills and the unconformity between Archean and Proterozoic rocks. Present barite production is obtained from veins in rocks of the Cobalt Embayment. Celestite has not been reported from the Southern Province. Fluorite, on the other hand, is widespread as gangue in barite and sulphide veins but has not been produced commercially from any of these deposits.

Grenville Province

The southwestern part of the Grenville Province north of the St. Lawrence Platform in southeastern Ontario and southwestern Quebec contains many deposits and occurrences of Ba, Sr and F. Limited production of all three elements has been reported. Barite was mined in the Gatineau region north of the Ottawa River and occurs elsewhere as a gangue in a wide variety of veins and replacement deposits in the southern Grenville Province. Celestite was mined near Calabogie, Ontario and has been reported in fluorite veins at Madoc, Ontario and elsewhere. Fluorite was produced mainly from the Madoc area, Canada's second largest source of the mineral, and also to a limited degree from Cardiff Township, Ontario.

Appalachian Orogen

The rocks of the Appalachian Orogen have yielded the principal Canadian commercial supplies of all three elements. Production has been from veins and replacement deposits mainly in the southern part of the orogen in rocks that have been affected by the Acadian and Taconic orogenies. Deposits containing one or more of the three elements occur at Hayesville, New Brunswick, in western Nova Scotia, in eastern Nova Scotia, at Belleoram, near Whitbourne, Newfoundland, in western and southeastern Newfoundland and in rocks deformed during the Taconic Orogeny along the south shore of the St. Lawrence River, Quebec. Other deposits are present in rocks that were deformed and invaded by granitic plutons during the Acadian Orogeny.

Barite was produced from the Walton Mine, central Nova Scotia, Canada's former main source of the mineral. This orebody occurs near the Horton-Windsor contact in the Maritime Fold Belt. Barite is more widely distributed than minerals of strontium and fluorine and it occurs both in monomineralic veins and replacement deposits as well as with metallic sulphides as a gangue material.

Celestite production has been from deposits associated with Carboniferous evaporites on Cape Breton Island, Nova Scotia. Reserves have been estimated for similar deposits on Port au Port Peninsula, Newfoundland. The mineral is also reported at other localities, including a significant deposit at Dorchester, New Brunswick.

Fluorite was produced from veins at St. Lawrence, Newfoundland, Canada's main source of the mineral. It also occurs in greisen-skarn deposits in central and southern New Brunswick and in pegmatites in central Nova Scotia.

Province du lac Supérieur

La province du lac Supérieur dispose d'un certain nombre de gisements et de venues de baryum et de fluor. La production de baryum s'est bornée à l'exploitation de quelques petits filons de baryte dans la zone volcanique d'Abitibi. On n'y a pas extrait de fluorine bien qu'on en retrouve en petites quantités dans des dykes de pegmatite, aux limites de la zone volcanique d'Uchi et de la zone de gneiss d'English River dans le district de Bird River au Manitoba. De la fluorine est associée à de la molybdénite, près du batholite de Lacorne dans la portion de la zone volcanique d'Abitibi située au Québec.

Province du Sud

Il existe un grand nombre de gisements et de venues de baryte dans la province du Sud, surtout dans la zone de plissements du Pénokéen dans le district de Thunder Bay et dans la baie de Cobalt. Dans le district de Thunder Bay, des veines de baryte ont été exploitées et le minéral est communément présent sous forme de gangue dans les filons d'argent et de métaux communs du district; ces derniers sont habituellement associés à des dykes et des sills de diabase de Keweenawan et à la discordance des roches de l'Archéen et du Protérozoïque. La production actuelle de baryte est tirée de filons dans de la roche de la baie de Cobalt. La province ne contiendrait pas de célestine. Par contre, la fluorine y est très répandue sous forme de minéral de gangue dans les veines de baryte et de sulfure, mais ne fait pas encore l'objet d'une production commerciale dans ces gisements.

Province de Grenville

Un grand nombre de gisements et de venues de Ba, de Sr et de F existent dans la partie sud-ouest de la province de Grenville, au nord de la plate-forme du Saint-Laurent, dans le sud-est de l'Ontario et le sud-ouest du Québec. On y a déclaré une production limitée des trois éléments. De la baryte a été extraite dans la région de la Gatineau, au nord de la rivière des Outaouais et on en retrouve ailleurs sous forme de minéraux de gangue de toute une gamme de filons et de gisements de substitution dans le sud de ladite province. L'extraction de la célestine s'est effectuée près de Calabogie (Ontario) et on en aurait trouvé dans des veines de fluorine à Madoc (Ontario) et ailleurs. La fluorine a surtout été tirée de la région de Madoc, deuxième source de ce minerai au Canada, mais aussi, dans une moindre mesure, du township de Cardiff en Ontario.

Orogène des Appalaches

Les roches de l'orogène des Appalaches contiennent les principaux approvisionnements commerciaux du pays des trois éléments. Ils sont tirés de filons et de gisements de substitution, surtout dans le sud de l'orogène, dans de la roche qui a subi l'influence des orogénèses acadienne et taconique. Des gisements contenant un ou plusieurs des trois éléments se trouvent à Hayesville (Nouveau-Brunswick), dans l'ouest et l'est de la Nouvelle-Écosse, à Belleoram près de Whitebourne (Terre-Neuve), dans l'ouest et le sud-est de Terre-Neuve et dans des roches déformées au cours de l'orogénèse du Taconique, le long de la rive sud du fleuve Saint-Laurent, au Québec. On retrouve d'autres dépôts dans des roches que des plutons granitiques ont déformées et envahies durant l'orogénèse de l'Acadien.

Il y a eu production de baryte à la mine Walton, dans le centre de la Nouvelle-Écosse. Cette masse minéralisée a déjà été la principale source de ce minéral au Canada et se situe près de la zone de contact de Horton et de Windsor, dans la zone de plissements des Maritimes. La baryte y est plus largement répandue que les minéraux de strontium et de fluor et on en trouve tant dans des filons à un seul minerai et des gisements de substitution que dans la gangue des sulfures métalliques.

De la célestine a été extraite des gisements associés aux évaporites du Carbonifère, dans l'île du Cap-Breton, en Nouvelle-Écosse. Les réserves de gisements similaires dans la péninsule Port-au-Port (Terre-Neuve) ont été évaluées. On signale la présence du minéral à d'autres endroits, notamment à Dorchester (Nouveau-Brunswick) où il y en aurait un gisement important.

Les filons de fluorine de St. Lawrence (Terre-Neuve) ont été exploités; il s'agit de la principale source canadienne de cette substance. On en retrouve également dans des accumulations de greisen et skarn, au centre et dans le sud du Nouveau-Brunswick, et dans des pegmatites situées dans le centre de la Nouvelle-Écosse.

USES

Barite was produced primarily for use in paints until 1926 when the utility of barite-weighed drilling muds was recognized by the oil and gas industry. The demand for barite increased greatly and has paralleled the growth in demand for oil and natural gas. The mineral is used as an extender or filler in a variety of products, an additive in glass and ceramic products and as a heavy aggregate material for the construction industry. Finely ground barite is used as a filler, extender or weighting agent in rubber products, linoleum, plastics, paper products, and brake linings. It is required by the electronics industry for the manufacture of ferrite ceramic permanent magnets.

Celestite is used to produce a variety of strontium chemicals for a number of products and industrial uses that include pyrotechnic applications, glass and ceramics, metallurgy, fillers and pharmaceuticals. Strontium carbonate is added to glass batches to make X-ray retardant glasses for cathode ray tube face plates. Metallic strontium alloys are used to remove gas from vacuum tubes, as metallurgical scavengers to purify metals, and as a trace additive to increase the hardness and durability of lead and copper.

The principal uses of fluorite are in the manufacture of hydrogen fluoride, as a metallurgical flux, in ceramic products and in a number of other industrial processes. Hydrofluoric acid has an important use as a catalyst in the manufacture of alkalate, an ingredient in high octane fuel blends, in steel pickling, enamel stripping, glass etching and polishing and electroplating operations. Elemental fluorine is used in the manufacture of uranium hexafluoride, sulphur hexafluoride and halogen fluorides. Uranium hexafluoride is used in the manufacture of uranium fuels. Inorganic fluorides are used in insecticides, preservatives, antiseptics, ceramic additives, electroplating solutions, fluxes, antioxidants, and as a trace additive to toothpaste. The steel industry uses fluorite as a flux in the manufacture of steel. The glass industry use fluorite to manufacture white or opaque enamels and glasses.

WORLD PRODUCTION

World production of barite in 1981 (including the Communist block countries) is estimated at 7.8 million tonnes in comparison with 6.7 million tonnes in 1979. More than 80 to 90 per cent of production was consumed in oil and gas well drilling operations. Dependence on the drilling industry as the principal market means that demand is subject to geographical shifts as exploration for oil and gas moves into new areas. The low value and heavy weight of barite concentrates make production and transportation costs and tariffs, and import and export controls, critical factors in the profitable operation of a barite mine. Consequently, new sources of barite are usually sought close to markets, leading to a geographically widely dispersed production base.

Celestite is a major source, and strontianite a minor source of strontium, Celestite is mined in several countries but there is a limited demand (40 000 to 50 000 tonnes per year) and the market is restricted mainly to the U.S.S.R., Europe, United States and Japan. World consumption grew from 5000 tonnes per year in 1920 to 40 907 tonnes per year in 1981, with sharp fluctuations upwards in times of major wars because of the use of strontium chemicals in pyrotechnics and ammunition. World reserves are known to be large although details regarding location, tonnage and grade are lacking. Technological advances in non-military products such as glass for TV tubes, special lubricants and electronic equipment has not led to the anticipated major growth in demand.

Fluorite and, increasingly, fluorapatite are the major sources of fluorine. Fluorite is mined in many countries and the byproduct, fluorsilicate, is recovered from chemical fertilizer plants processing ores from sedimentary phosphorite beds in southeastern United States. World production of 4.94 million tonnes in 1981 is little changed from 1979.

UTILISATIONS

La baryte était surtout utilisée dans les peintures jusqu'en 1926, année ou l'industrie du pétrole et du gaz a reconnu l'utilité des boues de forage alourdies de baryte. La demande de baryte a considérablement augmenté et a atteint le niveau de croissance de la demande de pétrole et de gaz naturel. Ce minéral est utilisé comme allongeant ou charge pour toute une gamme de produits, comme additif pour la fabrication du verre et de la céramique et comme aggrégat lourd dans le secteur de la construction. La baryte broyée finement sert de charge, d'allongeant ou d'agent d'alourdissement pour les produits de caoutchouc, le linoleum, les plastiques, les produits en papier et les garnitures de freins. L'industrie de l'électronique emploie cette substance pour fabriquer des aimants permanents de ferrite et céramique.

La célestine est utilisée pour produire une variété de produits chimiques à base de strontium qui entrent dans la composition d'un certain nombre de produits et qui servent à divers usages industriels, entre autres les pièces pyrotechniques, le verre et la céramique, la métallurgie, les charges et les produits pharmaceutiques. Du carbonate de strontium est ajouté à du verre en vue de la fabrication d'écrans cathodiques à l'épreuve des rayons X. Les alliages métalliques de strontium servent à retirer les gaz des tubes à vide; ils sont également utilisés comme épurateurs métallurgiques pour purifier les métaux et comme additifs de trace pour accroître la dureté et la durabilité du plomb et du cuivre.

La fluorine est surtout employée pour la fabrication de fluorure d'hydrogène et de produits de céramique, comme fondant métallurgique et pour un certain nombre d'autres procédés industriels. L'acide fluorhydrique sert de catalyseur lors de la fabrication d'alcalate, composante des mélanges de carburant à indice d'octane élevé. Il est également utilisé pour le décapage de l'acier et de l'émail, pour l'attaque et le polissage du verre et la galvanoplastie. Le fluor à l'état d'élément entre dans la composition de l'hexafluorure d'uranium, de l'hexafluorure de soufre et des fluorures halogènes. L'hexafluorure d'uranium entre dans la compositon des combustibles à base d'uranium et les fluorures non organiques dans celle des insecticides, des agents de préservation, des antiseptiques, des additifs pour céramique, des solutions de galvanoplastie, des fondants, des antioxydants et, en quantités minimes, des additifs pour pâte dentifrice. L'industrie de l'acier se sert de fluorine comme fondant lors de la fabrication de l'acier et l'industrie du verre, pour fabriquer des émaux et du verre blancs et opaques.

PRODUCTION MONDIALE

En 1981, la production mondiale de baryte (y compris dans les pays du bloc communiste) a été évaluée à 7,8 millions de tonnes, contre 6,7 millions de tonnes en 1979. Entre 80 et 90 % de la production ont été consommés par le forage des puits de pétrole et de gaz. Étant donné que l'industrie du forage constitue le principal débouché de la baryte, la demande du minéral est assujettie aux déplacements du secteur, au fur et à mesure que les travaux d'exploration du pétrole et du gaz s'effectuent dans de nouvelles régions. Ainsi, la faible valeur et le poids élevé des concentrés de baryte font des coûts et des tarifs de production et de transport ainsi que des contrôles des importations et des exportations, des facteurs critiques de la rentabilité des mines de baryte. Par conséquent, on tente habituellement de trouver de nouvelles sources de ce minéral à proximité des marchés, mesure qui entraîne la grande dispersion géographique des installations de production.

La célestine est une source majeure et la strontianite une source mineure de strontium. La célestine est extraite dans plusieurs pays, mais sa demande est restreinte (40 000 à 50 000 tonnes par année) et ses débouchés de marché surtout limités à l'URSS, à l'Europe, aux Etats-Unis et au Japon. La consommation modiale est passée de 5 000 à 40 907 t/a entre 1920 et 1981, avec des fluctuations à la hausse trés marquées en temps de guerre, vu l'utilisation des produits chimiques à base de strontium comme composantes des pièces pyrotechniques et des munitions. Les réserves mondiales sont considérables bien qu'on manque de détails concernant leur emplacement, leur ampleur et leur teneur. Les progrès techniques effectués dans le secteur non militaire, par exemple les tubes cathodiques, les lubrifiants spéciaux et le matériel électronique, n'ont pas mené à l'important accroissement prévu de la demande.

La fluorine et, de plus en plus la fluorapatite, sont les principales sources de fluor. La fluorine est extraite dans un grand nombre de pays et son sous-produit, le silicofluorure, est récupéré des usines d'engrais chimiques qui effectuent le traitement du minerai extrait des couches sédimentaires de phosphorite du sud-est des États-Unis. La production

Mexico ranks as the world's largest supplier of fluorite, accounting for about 25 per cent of world production. The U.S.S.R., the world's second largest producer of fluorite concentrates at 550 000 tonnes, imports another 500 000 tonnes from sources in satellite countries to meet domestic requirements. Thailand is one of the largest producers of fluorite concentrates in southeast Asia, with production being shipped mainly to Japan.

CANADIAN CONSUMPTION

Canadian consumption of barite in 1980 was estimated at 138 829 tonnes, 90 per cent of which was consumed by the oil and gas drilling industry. Less than 10 per cent is consumed in varnish and paints and less than 5 per cent in glass and glass products, rubber goods and unspecified products. Canada imported 45 157 tonnes (1980) from the United States.

Canada's minor requirements for celestite are mainly satisfied by imports from the United States. Because demand is so small, celestite import data are not recorded.

In 1979 Canada imported 167 904 tonnes and consumed 107 004 tonnes of fluorite. This is used mainly as a metallurgical flux and to a lesser degree in the chemical industries.

GEOCHEMISTRY

Barium

Barite forms a more or less continuous isomorphous solid solution series with Ca, Sr, Ra, and Pb sulphates that includes angleso-barite, baryto-celestite and calcio-barite. In the carbonate mineral Ba^{2+} replaces Ca^{2+} in members of the aragonite series. Barium occurs in the crystal lattices of several silicate minerals, chiefly substituting for potassium in feldspars and micas. The element occurs in the celsian (Ba-feldspar) molecule present in trace to minor amounts in most potash feldspars. Less commonly Ba substitutes for Ca in the structure of rock-forming silicates (plagioclase, pyroxene, mica and amphibole), phosphates (apatite) and carbonates (calcite).

Barium occurs in a variety of unconsolidated and consolidated clastic sedimentary rocks, including deep sea, shallow water and terrestrial sediments. Submarine barium-rich areas commonly underlie zones of intense biological activity or occur near oceanic ridges where the element may have been contributed from volcanic sources. Barium in an abyssal environment may be absorbed on clays, manganese oxides or the zeolite mineral phillipsite. On land, residual soils, such as those in southeastern Missouri, may contain economic concentrations of barite. Barite also occurs in Recent placers and lag gravels in the Cordillera of Western Canada and the United States.

Sedimentary rocks formed through chemical processes are also commonly enriched in barium. These are illustrated by the high-grade baritites off the Florida coast and baritite in the Devonian rocks of northeastern British Columbia and eastern Yukon Territory. Barite precipitates at points where barium-rich waters mix with sulphate-bearing brines.

Trace amounts of barium occur in fossil fuels, marine plants, marine animals and bacteria. Black siliceous oozes or clays accumulate in anaerobic environments inhabited by sulphate-reducing bacteria. The latter live on the organic debris, attack clastic or diagenetic barite, reduce the sulphate to sulphide and freed and barium goes into solution as part of the diagenetic process. The sulphide ion combines with available iron to form marcasite or pyrite and the soluble barium recombines with sulphate when a new supply of the cation is encountered.

Barium-bearing minerals include oxides, carbonates, nitrates, sulphates, selenites, phosphates, arsenates, vanadates and silicates but only a few contain barium as a major constituent. Only one of these mineral classes, the carbonates represented by witherite and barytocalcite, are an economic and a possible source of the element respectively.

mondiale, à 4,94 millions de tonnes en 1981, est sensiblement la même qu'en 1979. Le Mexique est le principal fournisseur mondial de fluorine, avec environ 25 % de la production mondiale. L'URSS se classe au deuxième rang des producteurs de concentrés de fluorine et, en plus des 550 000 tonnes qu'elle produit, elle doit en importer 500 000 autres tonnes, de ses pays satellites, afin de répondre à ses besoins. La Thaïlande est l'un des plus grands producteurs de concentrés de fluorine du sud-est asiatique et sa production est surtout expédiée au Japon.

CONSOMMATION AU CANADA

La consommation canadienne de baryte en 1980 a été évaluée à 138 829 t qui ont été consommées à 90 % par l'industrie du forage du pétrole et du gaz. Moins de 10 % entrent dans la fabrication des vernis et des peintures et moins de 5 % dans les produits de verre, de caoutchouc et autres. En 1980, le Canada a importé des États-Unis quelque 45 157 t de baryte.

L'importation de célestine des États-Unis permet au Canada de répondre à ses besoins minimes pour ce produit. Étant donné la faible demande, on ne recueille pas de données sur les importations.

En 1979, le Canada a importé 167 904 t et consommé 107 004 t de fluorine. On s'en sert surtout comme fondant métallurgique et, dans une moindre mesure, comme composante des produits chimiques.

GÉOCHIMIE

Baryum

La baryte forme, avec le Ca, le Sr, le Ra et les sulfates de Pb, une série plus ou moins continue de solutions solides isomorphes qui comprend l'angléso-baryte, la baryto-célestine et la calcio-baryte. Dans les minéraux carbonatés, le Ba^{2+} remplace le Ca^{+2} dans les membres de la série des aragonites. Le baryum se trouve dans les réseaux cristallins de plusieurs silicates, remplaçant surtout le potassium dans les feldspaths et les micas. L'élément se retrouve dans la molécule de celsiane (Ba-feldspath) qui est présente en quantité dont l'importance varie d'infinitésimale à mineure dans la plupart des feldspaths de potasse. Il arrive, mais moins souvent, que le Ba remplace le Ca dans la structure des silicates (plagioclase, pyroxène, mica et amphibole), des phosphates (apatite) et des carbonates (calcite) à l'origine de la formation des roches.

Le baryum se manifeste dans toute une gamme de roches sédimentaires clastiques consolidées et non consolidées, y compris les sédiments des profondeurs marines et des eaux peu profondes et les dépôts terrestres. Les zones sous-marines riches en baryum sont habituellement sous-jacentes à des zones d'activité biologique intense, ou se situent à proximité des crêtes océaniques où la présence de cet élément pourrait être due à de l'activité volcanique. Le baryum des milieux abyssaux peut être absorbé par des argiles, des oxydes de manganèse ou par de la phillipsite, minéral zéolitique. Sur la terre, les sols résiduels d'altération comme ceux qui se trouvent dans le sud-est du Missouri, peuvent contenir des concentrations rentables de baryte. On en trouve également dans les zones d'alluvions récents et les graviers délavés de la Cordillère, dans l'Ouest canadien et aux États-Unis.

Les roches sédimentaires dont la formation est due à des processus chimiques contiennent habituellement du baryum. La barytine à teneur élevée trouvée au large de la côte de la Floride et celle des roches dévoniennes du nord-est de la Colombie-Britannique et de l'est du Yukon en sont un exemple. La baryte se précipite à l'endroit où les eaux riches en baryum se mélangent aux saumures à teneur en sulfate.

Les combustibles fossiles, les plantes aquatiques, les animaux marins et les bactéries contiennent des traces de baryum. Les vases ou argiles siliceuses noires s'accumulent dans des milieux anaérobies peuplés par des bactéries réductrices de sulfate. Ces dernières vivent dans des débris organiques, attaquent la baryte clastique ou diagénétique, réduisent les sulfates en sulfures et, une fois libéré, le baryum se dissout lors du processus diagénétique. L'ion de sulfure se combine aux ions de fer présents pour former de la marcasite ou de la pyrite et le baryum soluble se mélange de nouveau au sulfate lorsqu'il entre en contact avec une nouvelle source de cations.

Les minéraux à teneur en baryum comprennent les oxydes, les carbonates, les nitrates, les sulfates, les sélénites, les phosphates, les arsenates, les vanadates et les silicates. Toutefois, le baryum est une composante majeure de seulement quelques uns de ces minéraux. Il n'y a que les carbonates, représentés par la withérite et la barytocalcite, qui peuvent constituer une source rentable de cet élément.

Strontium

The most common strontium minerals are celestite ($SrSo_4$) and strontianite ($SrCo_3$). The strontium ions have a valency of 2+ and are commonly bound to O^{2-}, OH^- and H_2O. Because it has an ionic radius between those of Ca and Ba and somewhat less than those of K+ and Pb+, Sr^{+2} can replace or by replaced by any of the four elements.

Strontium rarely forms independent minerals in igneous rocks. It does, however, substitute for calcium in lattices of early-formed plagioclase. In potash feldspar, it replaces potassium more readily than does barium because of the greater similarity in ionic radii between strontium and potassium. Strontium also occurs in micas, pyroxenes and amphiboles, although in micas, which have fewer calcium positions, it is less abundant than barium. The bulk of strontium in magma enters the early-formed, high-temperature feldspars of both igneous intrusive and extrusive rocks; thus magmas as a rule do not become enriched in strontium until late in the differentiation process.

Strontium occurs principally as celestite, rarely as strontianite, in a variety of chemical sediments. These include limestone, dolomite, aragonitic oolites, and sabhka and playa-type evaporites.

Strontium occurs in some coal seams, terrestrial animals, marine animals and bacteria, none of which produce economic deposits of the element.

Fluorine

The fluorine anion commonly substitutes isomorphously for OH^-, less commonly for O^{2-}, Cl^-, CO_3^{2-} and rarely in complex ions. For example F^- and OH^- substitute for one another to produce the mineral series fluorapatite-hydroxyapatite. Fluorine tends to accumulate in the igneous plutonic environment in which it has a strong affinity for SiO_2 in basaltic, granitic and alkalic magmas. The major fluorine-bearing minerals in granites include biotite, muscovite, hornblende, apatite, topaz, fluorite and tourmaline. Fluorite is more abundant in complex pegmatites than in the mineralogically simple pegmatites. Ultramafic and alkaline ultramafic rocks have a mineral fluorine content but the serpentinization process results in fluorine enrichment. The main host minerals in ultramafic rocks include phlogopite, biotite, serpentine, augite and hornblende.

Carbonatites in general exhibit a large range of fluorine concentration because the principal host minerals (fluorite, apatite and pyrochlore) show different concentration levels in different phases of the carbonatite. The volcanic rocks, in general, have a lower fluorine content than their intrusive equivalents although they show a parallel increase of F^- with increasing silica and alkali content.

Fluorine is enriched in some clastic sedimentary rocks. The element occurs in resistate minerals such as apatite and mica or adsorbed on clay minerals in shales, siltstones and mudstones. The amount of fluorine present is generally proportional to the clay content and to the amount of phosphatic minerals present.

Some chemical sediments including anhydrite, gypsum, salt, limestone and dolomite have anomalous fluorine contents. The average fluorine content is the same for both limestone and dolomite although the range of values is less for the latter rock type.

The fluorine minerals and dispersed fluorine in regionally metamorphosed rocks, greisens and skarns owe their fluorine content to some combination of primary sedimentation and subsequent metasomatic introduction. Fluorine is freed from clay, mica and other resistate minerals by rising temperature and pressure in the presence of water. In the case of metasomatism, the fluorine content is augmented by fluorine emitted by intrusive felsic stocks. The volatiles under high temperatures and pressures partially replace lime-rich sedimentary rocks to form marbles and skarns and in silicate-rich sedimentary rocks and granites to form hornfels and greisen respectively.

Strontium

Les minéraux de strontium les plus communs sont la célestine ($SrSo_4$) et la strontianite ($SrCo_3$). Les ions de strontium ont une valence de 2+ et sont habituellement liés à des O^{2-}, OH^- et H_2O. Parce qu'il a un rayon ionique qui se situe entre ceux du Ca et du Ba et qui est légèrement inférieur à ceux du K+ et du Pb+, le Sr^{+2} peut remplacer n'importe lequel de ces quatre éléments ou être remplacé par l'un d'eux.

Il est rare que le strontium forme des minéraux indépendants dans des roches ignées. Toutefois, il remplace le calcium dans les résaux de plagioclase formés depuis longtemps. Dans le feldspath potassique, il remplace plus facilement le potassium que ne le fait le baryum, en raison de la plus grande similitude entre les rayons ioniques du strontium et du potassium. On retrouve également de cet élément dans les micas, les pyroxènes et les amphiboles, bien qu'il soit moins abondant que le baryum dans les micas qui, en raison de leur structure, ne peuvent contenir beaucoup de calcium. La majeure partie du strontium dans les magmas est introduite dans les faldspaths, formés très tôt et à haute température, des roches ignées intrusives et extrusives. Par conséquent, les magmas, en règle générale, ne sont enrichis en strontium que vers la fin du processus de différentiation.

Le strontium se retrouve surtout sous forme de célestine et, rarement sous forme de strontianite, dans toute une gamme de sédiments chimiques, entre autres les calcaires, la dolomie, les oolites aragonitiques et les évaporites de sebkhas et de playas.

Certains filons houillers, certains animaux terrestres et marins et certaines bactéries contiennent du strontium, mais il ne s'agit pas de sources rentables de cet élément.

Fluor

Les anions de fluor se substituent communément, par isomorphisme, aux anions de OH^-, moins souvent à ceux de O^{2-}, de Cl^- et de CO_3^- et rarement aux ions complexes. Par example, le F^- et le OH^- peuvent se substituer l'un à l'autre pour produire la série de minéraux de fluorapatite – hydroxyapatite. Le fluor a tendance à s'accumuler dans des milieux de plutons ignés où il a de fortes affinités avec le SiO_2 des magmas basaltiques, granitiques et alcalins. Les principaux minéraux à teneur en fluor dans les granites comprennent les biotites, les muscovites, les hornblendes, les apatites, les topazes, les fluorines et les tourmalines. La fluorine se retrouve en plus grande quantité dans les pegmatites complexes que dans les pegmatites à minéralogie simple. Les roches ultramafiques et alcalines ont une teneur en fluor minéral mais le processus de serpentinisation permet l'enrichissement en fluor. Les principaux minéraux hôtes des roches ultramafiques comprennent la phlogopite, la biotite, la serpentine, l'augite et la hornblende.

En règle générale, les carbonatites peuvent avoir toute une gamme de concentrations en fluor, car les principaux minéraux hôtes (fluorine, apatite et pyrochlore) ont des concentrations qui varient selon les phases des carbonatites. Les roches volcaniques, en général, contiennent moins de fluor que leurs équivalents intrusifs, bien qu'on y dénote une augmentation du F^- qui corresponde à la hausse de la teneur en silice et en alcali.

Le fluor est enrichi dans certaines roches sédimentaires clastiques. On en retrouve dans certains minéraux résistants comme l'apatite et le mica, ou il est adsorbé dans les minéraux argileux des schistes argileux, des siltstones (aleurolites) et des pélites. La quantité de fluor est généralement proportionnelle à la teneur en argile et à la quantité de minéraux phosphatés présents.

Certains sédiments chimiques comme l'anhydrite, le gypse, le sel, le calcaire et la dolomie ont une teneur anormale en fluor. La teneur moyenne en fluor des calcaires et de la dolomie est la même, bien que l'échelle des valeurs soit moindre pour cette dernière.

La teneur en fluor des minéraux fluorés et du fluor dispersé des roches métamorphisées par endroits, des greisens et des skarns est due à une certaine combinaison de sédimentation primaire et de métasomatisme ultérieur. Le fluor est libéré des argiles, des micas et d'autres minéraux résistants par l'augmentation de la température et de la pression en présence d'eau. Dans le cas d'une métasomatose, le fluor émis par de petits massifs intrusifs felsiques ajoute à la teneur en ce minéral. Les matières volatiles qui sont soumises à des températures et des pressions élevées remplacent partiellement les roches sédimentaires riches en calcaire pour former des marbres, des skarns et, dans les roches sédimentaires riches en silicate et les granites, pour former des cornéennes et des greisens respectivement.

Trace amounts of fluorine occur in coal ash, terrestrial plants, terrestrial animals, and marine animals. The element is accumulated by life processes and diagenesis of the sedimentary host rocks. Excessive concentrations of fluorine are highly toxic whereas trace amounts contribute to the strengthening of animal bones and the hardening of tooth enamel.

WORLD OUTLOOK

Barite (barium)

The demand for barite is to a considerable extent coupled with oil exploration activity. This may result in the activation of new mines nearer the new oil exploration areas. For example oil exploration on the Alaska north slope in the Beaufort Sea and in the Canadian Arctic Islands may speed the development of the bedded baritites in Yukon Territory and District of Mackenzie.

In the future more barite will be recovered from mill tailings and waste dumps of exhausted base metal mines in the Canadian Cordillera and Appalachia.

The only foreseeable deterrent to continued development of barite mines would be the production and sale of a competitive substitute for a drilling mud and weighting agent. "Fer-O-Bar", developed and sold by Sachtleben Chemie GMBH, West Germany is available commercially. It is produced by calcining pyritic ores. However, there is skepticism regarding cost competitiveness, abrasive qualities, chemical reactivity and viscosity-suspension characteristics under all possible conditions that may be encountered.

Other technological developments will continue and these may capture a larger proportion of the current barite production. The long list of commercial uses developed in this century will also continue to support the demand for barite.

Celestite (strontium)

Celestite producers study with interest technological developments that might enlarge the existing market for the mineral. Among the most promising developments is the use of X-ray absorbing, strontium-glass face plates on colour TV tubes to minimize risk of exposure to X-radiation from the tube circuitry. European TV sets are less powerful so the electronic designers contend that a circuit modification would alleviate the problem and this may have been accomplished. American and Japanese manufacturers have been using the new tube whereas the European manufacturers have not. Consequently, the expected increase in European market did not take place. Half of the celestite imported into the United States or approximately 15 per cent of world production is used for this purpose.

A more promising development in the electronics field – the manufacture of strontium ferrite permanent magnets – has increased demand. The quality of these magnets has resulted in their use in a variety of electrical and electronic circuits. There has been an increase in the use of strontium nitrate in pyrotechnics for red, highway safety flares. A small but promising demand has developed for strontium chemicals in the production of electrolytic zinc. This technique is used in some Canadian and American smelters.

World supplies of celestite are adequate and Mexican and Spanish producers are the free world's principal source of the mineral. Great Britain stopped production in Yate, Gloucestershire in September 1974. Kaiser Celestite Ltd., shut down operations of its Cape Breton, Nova Scotia, mine in December 1976, because of slow market growth and failure to find a purchaser or a joint venture partner.

Fluorite (fluorine)

The performance of the fluorite industry necessarily parallels development in the steel, chemical and aluminum industries, which together account for 95 per cent of fluorite consumption. The conversion from open hearth to basic oxygen process (BOP) for steelmaking, and

On retrouve des traces du fluor dans les cendres de charbon, les plantes terrestres et les animaux terrestres et marins. L'élément s'accumule dans les êtres vivants et par diagénèse des roches sédimentaires encaissantes. Une trop grande concentration de fluor est extrêmement toxique tandis qu'à l'état d'oligo-élément, ce minéral est excellent pour renforcer les os et l'émail des dents.

PERSPECTIVES MONDIALES

Baryte (baryum)

La demande de baryte est largement liée aux travaux d'exploration pétrolière, ce qui pourra entraîner la mise en service de nouvelles mines à proximité des nouvelles zones d'exploration pétrolière. Par exemple, l'exploration sur le versant nord de la chaîne de l'Alaska, dans la mer de Beaufort, dans les îles canadiennes de l'Arctique, pourra accélérer le rythme de la mise en valeur de la barytine stratifiée trouvée au Yukon et dans le district de Mackenzie.

À l'avenir, on récupérera de plus grandes quantités de baryte des résidus de broyage et des terrils des mines de métaux communs épuisées dans la Cordillère et les Appalaches.

Le seul empêchement prévisible à la mise en valeur continue des mines de baryte serait la production et la vente d'un substitut concurrentiel pour la fabrication des boues de forage et des agents alourdissants. Le "Fer-O-Bar", produit fabriqué et vendu par la Sachtleben Chemie GMBH d'Allemage de l'Ouest, est maintenant disponible sur le marché. Il provient de la calcination des minerais pyriteux. Toutefois, certains doutes demeurent quant à sa compétitivité sur le plan des coûts, ses propriétés abrasives, son pouvoir réactif et ses caractéristiques de viscosité et de suspension dans toutes les conditions d'utilisation possibles.

La poursuite des progrès techniques pourra créer de nouveaux débouchés pour la production actuelle de baryte. De plus, la multitude des usages commerciaux élaborés durant le siècle permettra aussi de soutenir la demande.

Célestine (strontium)

Les producteurs de célestine étudient avec intérêt tout progrès technique qui pourrait majorer le nombre de débouchés pour ce minéral. Parmi les réalisations les plus prometteuses, on retrouve le verre à base de strontium à l'épreuve des rayons X que l'on utilise dans la fabrication des écrans de téléviseur couleurs conçus afin de minimiser les risques d'exposition au rayonnement provenant de l'appareil. Les téléviseurs européens sont moins puissants et les concepteurs en électronique soutiennent qu'une modification des circuits atténuerait le problème, mesure qui, semble-t-il, aurait déjà été prise. Les fabricants américains et japonais se servent du nouvel écran mais non les Européens. Par conséquent, l'augmentation prévue sur le marché européen ne s'est pas produite. La moitié de la célestine importée aux États-Unis, soit environ 15 % de la production mondiale, sert à cette fin.

Une réalisation plus importante dans le domaine de l'électronique a fait augmenter la demande: il s'agit de la fabrication d'aimants permanents de ferrite et strontium. Vu leur qualité, ces aimants sont utilisés dans toute une gamme de circuits électriques et électroniques. De plus, l'industrie des pièces pyrotechniques utilise une plus grande quantité de nitrate de strontium pour fabriquer des feux de détresse rouges. Un débouché de faible envergure mais prometteur a vu le jour grâce à l'utilisation des produits chimiques à base de strontium pour la fabrication du zinc électrolytique; cette technique est employée dans certaines fonderies du Canada et des États-Unis.

Les approvisionnements mondiaux en célestine sont suffisants et proviennent en grande partie des principaux producteurs de ce minéral dans les pays occidentaux, soit le Mexique et l'Espagne. En septembre 1974, la Grande-Bretagne a mis fin à la production à Yate, dans le Gloucestershire. La Kaiser Celestite Ltd a fermé sa mine dans l'île du Cap-Breton (Nouvelle-Écosse) en décembre 1976 en raison de la faible croissance du marché et du fait qu'elle ne pouvait trouver d'acheteur ou de partenaire.

Fluorine (fluor)

Le rendement de l'industrie de la fluorine correspond nécessairement à celui des secteurs de l'acier, des produits chimiques et de l'aluminium, étant donné qu'ils consomment à eux seuls 95 % de la production de ce minéral. La substitution des fours convertisseurs aux fours Siemens-Martin

vigorous growth in the chemical and aluminum industry during the 1960s accelerated fluorite consumption. The BOP steelmaking process requires three times as much fluorite as the older open hearth technology. On the other hand there is evidence of a trend to use higher grade concentrates either pelletized or briquetted to increase efficiency by reduction of dust losses. A change is being made in slag chemistry involving the partial or complete replacement of fluorite by dolomite. Both of the latter developments will tend to reduce the demand for fluorite in the steel industry.

Production of aluminum electrolytes from the fluosilicic acid byproduct of phosphate fertilizer manufacture, combined with recovery and recycling of fluorine in the alumina reduction process, will have a major effect on the world demand for fluorite. Consequently the fluorite requirements of the aluminum industry will be significantly reduced.

Demand in the chemical industry will continue to grow. Fluorine, the most electronegative of all elements, reacts with all organic and inorganic substances and thus has much potential as an industrial chemical. The controversy relating to the hypothesis that chlorine from chlorofluorocarbon aerosol propellants is responsible for the depletion of the ozone shield in the stratosphere, thus increasing the risk of skin cancer, has aroused public opinion and reduced the sale of such chemicals. An intensive search is underway to find low chlorine or chlorine-free propellants. The success or failure of this research will influence market demand for chemical grade fluorite.

Nuclear power future will influence the demand for fluorite. Fluorine chemicals are an important reagent used in the manufacture of nuclear fuels. If increasing electricity demand results in the construction of a significant new nuclear generating capacity, this will increase the markets for fluorine chemicals.

The largest potential source of fluorine is the fluorapatite of bedded phosphate rocks that are the main feedstock of chemical fertilizer plants. In the United States alone there is a potential of 2.54 billion tonnes of fluorine from this source. However, at the present, fluorine cannot be recovered economically from such sources except as a byproduct of fertilizer manufacture.

In summary, the outlook for fluorite is for slower growth in consumption over the next few years as a result of technological changes, public demand for lower levels of atmospheric and water contamination, and the general state of the economy. In the longer term, however, there is little doubt that the unique properties of this versatile element will result in growth in demand.

CANADIAN RESOURCES

Barite

Canadian barite occurrences on record number between 300 and 400. They occur in District of Mackenzie, Yukon Territory, British Columbia, Ontario, Québec, Nova Scotia and Newfoundland. The Yukon Territory and District of Mackenzie resources are mainly stratiform deposits in the Upper Devonian-Lower Mississippian sedimentary rocks of the Mackenzie Fold Belt and the Selwyn Basin. Probably the greatest barite resource in Canada, they contain much direct shipping ore. However, transportation difficulties will delay development. The extension of Arctic drilling for oil and gas will likely influence further development and marketing of these large resources. British Columbia resources include small vein deposits (e.g. Brisco and Parson properties) and barite-rich tailings of lead-zinc mines (e.g. Mineral King with more than 250 000 tonnes and the Silver Giant) and the massive stratiform barite exposed on Sulphur Creek east of Muncho Lake. The presence of barite as a gangue mineral in sulphide ores suggests the tailing ponds for the Tulsequah Chief, Highland, Kootenay Florence and the Lynx mines should be sampled as potential future sources of the mineral. Ontario and Québec deposits are characteristically in the form of small-tonnage veins. The Walton mine in Nova Scotia is exhausted and known resources in this province are limited to the Brookfield deposit

pour la fabrication de l'acier et la croissance vigoureuse dans les secteurs des produits chimiques et de l'aluminium durant les années 60 ont haussé la consommation de fluorine. Le processus de la fabrication de l'acier dans des fours convertisseurs demande trois fois plus de fluorine que l'ancien procédé Siemens-Martin. Par contre, il semble qu'on ait tendance à utiliser des concentrés de meilleur qualité, sous forme de boulettes ou de briquettes, pour accroître l'efficacité en réduisant les pertes dues à la poussière. Dans le domaine de la chimie des scories, on procède à un changement qui comporterait le remplacement partiel ou total de la fluorine par la dolomie. Ces deux changements auront tendance à faire baisser la demande de fluorine dans l'industrie de l'acier.

La production d'électrolytes d'aluminium à partir de l'acide fluosilicique obtenu comme sous-produit de la fabrication des engrais phosphatés, alliée à la récupération et au recyclage du fluor utilisé dans le procédé de réducton de l'alumine, aura des répercussions importantes sur la demande mondiale de fluorine; les besoins en fluorine de l'industrie de l'aluminium s'en trouveront considérablement réduits.

La demande dans l'industrie des produits chimiques continuera à croître. Le fluor, qui est l'élément le plus électronégatif, réagit avec toutes les substances organiques ou non organiques et renferme donc beaucoup de potentiel en tant que produit chimique industriel. Cependant, la controverse qui entoure l'hypothèse selon laquelle le chlore des aérosols de chlorofluorocarbone est responsable de l'érosion de la couche d'ozone de la stratosphère et, donc, de l'augmentation des risques de cancer de la peau a réveillé l'opinion publique et réduit la vente de produits chimiques de ce genre. On tente actuellement de trouver des aérosols à teneur faible ou inexistante en chlore. L'issue de ces recherches influencera la demande commerciale de fluorine de qualité chimique.

Les perspective d'avenir de l'industrie nucléaire exerceront également une influence sur la demande de fluorine. Les produits chimiques à base de fluor sont d'importants réactifs utilisés dans la fabrication des combustibles nucléaires. Les débouchés de marché pour ces produits augmenteront si l'accroissement de la demande d'électricité entraîne la construction d'un nombre important de nouvelles centrales nucléaires.

La fluorapatite des roches phosphatées stratifiées, qui est la principale charge d'alimentation des usines d'engrais chimiques, s'avère la plus grande source possible de fluor. Aux États-Unis uniquement, il serait possible d'en tirer 2,54 milliards de tonnes. À l'heure actuelle, toutefois, il n'est pas rentable de récupérer ainsi le fluor, sauf sous forme de sous-produit de la fabrication d'engrais.

Bref, l'accroissement plus lent de la consommation de fluorine au cours des quelques prochaines années, suite aux changements techniques, aux exigences du public concernant la diminution de la pollution de l'air et de l'eau et à l'état général de l'économie, constitue les perspectives pour ce minéral. À long terme, toutefois, il fait peu de doute que les propriétés uniques de cet élément polyvalent entraîneront un accroissement de sa demande.

RESSOURCES CANADIENNES

Baryte

Les venues de baryte enregistrées au Canada se chiffrent entre 300 et 400. Elles se trouvent dans le district de Mackenzie, le Yukon, la Colombie-Britannique, l'Ontario, le Québec, la Nouvelle-Écosse et Terre-Neuve. Au Yukon et dans le district de Mackenzie, les ressources se manifestent surtout sous forme de dépôts stratiformes dans des roches sédimentaires du Dévonien supérieur et du Mississipien inférieur de la zone de plissements de Mackenzie et du bassin Selwyn. Il s'agit probablement des plus importantes sources de baryte au pays et les roches contiennent beaucoup de minerai pouvant être expédié directement. Toutefois, les difficultés de transport en retarderont la mise en valeur. L'accroissement des travaux de forage du pétrole et du gaz dans l'Arctique influencera vraisemblablement la mise en valeur et la commercialisation plus poussée de ces ressources d'envergure. En Colombie-Britannique, les ressources se retrouvent sous forme de petits filons (par ex., les propriétés de Brisco et Parson), de résidus riches en baryte des mines de plomb et de zinc (par ex., les mines Mineral King, avec plus de 250 000 t et Silver Giant) et de gisements stratiformes de baryte massive en affleurement, à Sulphur Creek, à l'est du lac Muncho. Vu la présence de baryte dans le minéral de gangue des minerais sulfurés, les résidus des mines Tulsequah Chief,

(62 000 tonnes at a grade of 50.4% $BaSO_4$) and several veins at Lake Ainslie East which have combined reserves of 4 000 000 tonnes at 28.68 to 71.14% $BaSO_4$ (Felderhof, 1979; Zurowki, 1972). Production from the latter deposit is awaiting development of a milling technique to separate fluorite and barite. The Buchans, Newfoundland, massive sulphide deposit contained 25% barite and, consequently, tailings (more than 250 000 tonnes with 40% $BaSO_4$) which have been ponded since 1968 are a significant resource of partly-milled barite. Barite production from these sources began in August 1981.

Celestite

Canadian celestite deposits and occurrences on record number 36 and they are all small. They occur in central British Columbia, Nova Scotia and Newfoundland. The fluorite orebody on the Consolidated Rexspar Uranium property, British Columbia, is a potential source of celestite as a byproduct of fluorite production. The Kaiser Celestite mine at Lake Enon, Nova Scotia, although it was a major producer of the mineral for several years, closed in 1976 due to market decline. A total of 40 000 tonnes of celestite ore remains in a stockpile and 950 000 tonnes of 60-65% $SrSO_4$ is still in place. Small deposits are known on Port au Port Peninsula, Newfoundland, including the Gillams Cove (18 000 tonnes) and Ronan (152 000 of mixed barite-celestite) bodies. The world production of celestite in 1981 was 40 907 tonnes, consequently published Canadian reserves for Port au Port Peninsula and Lake Enon (Kaiser Celestite) would represent 30 years world supply barring a major war that would produce a sharp increase in demand for the mineral. Large reserves of celestite are currently unknown and future production from presently known small deposits depends on low production costs and proximity to world markets.

Fluorite

Canadian fluorite deposits and occurrences on record number more than 200, a few of which constitute significant resources. Occurrences of potential value are in British Columbia, Nova Scotia and Newfoundland. The Rexspar property in central British Columbia has reserves of fluorite ore (1 000 000 tonnes at a grade of 29% CaF_2) that may be recovered as a byproduct of uranium mining. The Tam fluorite-witherite body at Liard Crossing, northeastern British Columbia has more than 500 000 tonnes of 36.7% CaF_2 and potential for the discovery of additional ore. The Rock Candy mine, north of Grand Forks, British Columbia still has a few thousand tonnes of ore in place. Fluorite resources remain in the Madoc, Ontario area but high mining costs make early development unlikely (Guillet, 1964). Several vein deposits at Lake Ainslie East, Nova Scotia have combined reserves that exceed 4 000 000 tonnes of 7.02 to 23.23% CaF_2 and these may be mined when milling problems are resolved. ALCAN closed its fluorspar mines at St. Lawrence, Newfoundland in 1978, although a substantial resource of fluorite remains in the mines (9 144 000 tonnes at 35% CaF_2). The development of one or more of the properties noted here awaits improvements in market conditions.

Highland, Kootenay Florence et Lynx devraient, en qualité de sources possibles de minéral, faire l'objet de travaux d'échantillonnage. Les dépôts au Québec et en Ontario prennent habituellement la forme de filons de petite envergure. La mine Walton en Nouvelle-Écosse est épuisée et les réserves connues dans cette province se limitent au gisement Brookfield (62 000 t à teneur de 50,4 % en $BaSO_4$) et à plusieurs filons à Lake Ainslie East, dont les réserves globales s'élèvent à 4 000 000 t à teneur de 28,68 à 71,14 % en $BaSO_4$ (Felderhof, 1979; Zurowski, 1972). On attend la mise au point d'une technique de broyage permettant la séparation de la fluorine et de la baryte pour mettre en valeur cette dernière source. Le gisement de sulfure massif de Buchans (Terre-Neuve) contenait 25 % de baryte et, par conséquent, les résidus (plus de 250 000 t contenant 40 % de $BaSO_4$) entreposés dans des terrils depuis 1968 sont une source importante de baryte partiellement broyée. La production de baryte de ces sources a débuté en août 1981.

Célestine

Les 36 gisements et venues de célestine enregistrés au Canada sont tous de très petite envergure. On les retrouve dans le centre de la Colombie-Britannique, en Nouvelle-Écosse et à Terre-Neuve. L'amas minéralisé de fluorine de la propriété de la Consolidated Rexpar Uranium, en Colombie-Britannique, est une source possible de célestine obtenue comme sous-produit de la production de fluorine. La mine de la Kaiser Celestite à Lake Enon, en Nouvelle-Écosse, même si elle a été l'un des principaux producteurs de ce minéral durant plusieurs années, a été fermée en 1976 en raison du déclin des marchés. Les réserves contiennent encore 40 000 t de minerai de célestine et la mine, 950 000 t de minerai à teneur entre 60 à 65 % de $SrSO_4$. La péninsule Port-au-Port (Terre-Neuve) renferme de petits gisements, y compris ceux de Gillams Cove (18 000 t) et de Ronan (152 000 t de baryte et célestine). La production mondiale de célestine en 1981 s'est élevée à 40 907 t. Par conséquent, les réserves canadiennes publiées pour la péninsule Port-au-Port et pour Lake Enon (Kaiser Celestite) équivaudraient à des approvisionnements mondiaux pour 30 ans, sauf en cas de guerre majeure, phenomène qui entraînerait une hausse aigüe de la demande de ce minéral. On ne sait pas encore s'il existe de grandes réserves de célestine, et l'exploitation future des petits gisements actuellement connus dépendra de l'ampleur des coûts de production et de leur proximité des marchés mondiaux.

Fluorine

Au Canada plus de 200 gisements et venues de fluorine ont été enregistrés et quelques-uns d'entre eux constituent des sources importantes de ce minéral. Les venues pouvant avoir une certaine valeur se trouvent en Colombie-Britannique, en Nouvelle-Écosse et à Terre-Neuve. La propriété de la Rexpar, dans le centre de la Colombie-Britannique, contient des réserves de minérai de fluorine (1 million de tonnes à teneur de 29 % en CaF_2) qui peuvent être récupérées comme sous-produit de l'extraction de l'uranium. Le dépôt de fluorine et withérite Tam, à Liard Crossing, dans le nord-est de la Colombie-Britannique, renferme plus de 500 000 t à teneur de 36,7 % en CaF_2 et il est possible d'ajouter à ces réserves. La mine Rock Candy, située au nord de Grand Forks, en Colombie-Britannique, contient encore quelques milliers de tonnes de minerai. Il reste des ressources en fluorine dans la région de Madoc (Ontario), mais leur mise en valeur prochaine est invraisemblable vu les coûts élevés d'extraction (Guillet, 1964). Plusieurs filons à Lake Ainslie East (Nouvelle-Écosse) contiennent des réserves globales supérieures à 4 millions de tonnes dont la teneur en CaF_2 varie entre 7,02 et 23,23 %; ces dernières pourront être exploitées une fois que les problèmes de broyage auront été résolus. En 1978, l'Alcan a fermé ses mines de spath fluor de St. Lawrence (Terre-Neuve) malgré la quantité importante du minéral toujours présente (9 144 000 t à teneur de 35 % en CaF_2). La mise en valeur d'une ou de plusieurs des propriétés sus-mentionnées dépend de l'amélioration des conditions du marché.

INTRODUCTION

General Comments

Barium, strontium and fluorine were first identified in the late 18th century but extensive commercial exploitation did not develop until the present century. The elements are all minor constituents of crustal rocks, with the minerals barite ($BaSO_4$), witherite ($BaCO_3$), celestite ($SrSO_4$), strontianite ($SrCO_3$) and fluorite (CaF_2) being the main commercial sources. All three elements have been mined in Canada; barium intermittently since the turn of the century and continuously for the last forty years; strontium intermittently for sixty years and fluorine continuously for the last forty years and intermittently for the preceding forty years. Canada's former major barite producer, the Walton Mine in Nova Scotia, ceased operations in 1978 and our requirements for crude barite are now met by production from northern Ontario and southern British Columbia and by imports. Barium chemicals are imported from the United States. Closure of the Kaiser Celestite Mine, Nova Scotia, in 1976 terminated the most recent period of production of celestite in Canada and requirements for crude celestite and strontium chemicals must now be met by imports. Canadian production of fluorite ceased in 1978 with the closure of mines at St. Lawrence, Newfoundland. Crude fluorite and fluorine chemicals for domestic requirements are now imported from Mexico and the United States.

Although there is no current Canadian production of strontium and fluorine, and only minor production of barite, market conditions are constantly changing as a result of technological developments, changes in production costs and even national emergencies. These changes could lead to future Canadian production of any or all of the three elements and thus it is useful to have the geology and distribution of the three elements described in a comprehensive report.

Previous Work

Geological studies of barium, strontium and fluorine were first published by the federal government more than 50 years ago and by various provincial agencies more recently. These publications have been the source of much of the data compiled during this work and they are referred to frequently in this report.

Geological Survey of Canada personnel have maintained mineral catalogues since the initial work of Johnston (1915). Minerals in recent editions (Traill 1970; 1973) are alphabetically arranged by name and are also located with reference to the National Topographic System (N.T.S.), map numbers and province. These publications contain references to the earliest discoveries of barium, strontium and fluorine minerals in Canada. Wilson (1921; 1929) published a more complete description of fluorite occurrences and proposed a classification scheme together with conclusions regarding the geographical and geological distribution of the deposits. The later report (1929) covers fluorite deposits and occurrences known across the country as of May 1929. Production at that time came from deposits near Madoc, Ontario and Grand Forks, British Columbia. Other deposits and occurrences in several mining camps in British Columbia, the Northwest Territories, Ontario, Québec, New Brunswick and Nova Scotia were also described. Wilson used a three-fold classification scheme.

1. deposits associated with igneous rocks;
2. deposits associated with sedimentary rocks and;
3. deposits of uncertain lithological association and those of secondary origin.

Brief lists of characteristic mineral suites were included with the property descriptions. In addition, deposits in the United States, Great Britain, France, South Africa, Italy, Australia, Mexico, Spain, Norway, China, Austria and Greenland were briefly described. Fluorite, and to a lesser degree, cryolite, were the main fluorine-bearing minerals in the occurrences described. The former was used chiefly as a flux in metal smelting whereas cryolite was used as the electrolyte for reducing alumina to aluminum. At that time the market for fluorine was showing signs of growth as new uses for the element were being developed.

The former Mines Branch[1] published a number of reports on barite and fluorite in Canada (Spence, 1922; Ross, 1960; Bartley, 1961). Spence (1922) summarized Canadian barium and strontium mineral distributions, reserves, markets and prices of the elements and briefly described known occurrences of barite, witherite and celestite. Ross (1960) published a similar, although less detailed, report of Canadian barite deposits and occurrences, in which data on uses, specifications, consumption, foreign and domestic deposits, reserves and resources were presented. Between 1866 and 1959 Canada produced 3 048 479 tonnes of barite of which 94 per cent came from the Walton Mine, Nova Scotia; 5 per cent from British Columbia; and the balance from Ontario, Québec and Newfoundland. In 1959 Canada ranked third in barite exports in the non-communist world. Estimated reserves at that time were 1 984 140 tonnes with an additional estimated 4.4 million tonnes contained in tailings dumps of lead-zinc mines. Bartley (1961) reported on fluorite in Canada and discussed its physical and chemical properties, uses, specifications, market, market trends and Canadian deposits and prospects. Optimism was expressed about the growing demand for the mineral and the adequacy of known reserves but Bartley noted concern about the distance of known reserves from the main markets in the United States and Europe.

In 1966 the Mineral Resources Branch[2], commenced an annual publication of summary data on a variety of nonmetallic and metallic elements of commercial interest, including Ba, Sr and F[3]. Information contained in these publications contributes to Chapter 1 of this report.

Agencies of several provincial governments have published reports dealing with barite, celestite or fluorite. The Ontario Department of Mines (Guillet, 1963, 1964) and the Québec Ministère des Richesses Naturelles (Tiphane, 1972; Bourret, 1959) have published compilations of both fluorite and barite distribution in these provinces. Over a period of more than 70 years, the annual reports of the British Columbia Department of Energy, Mines and Petroleum Resources or its forerunners have described properties containing barite, celestite or fluorite. Hamilton (1968) of the New Brunswick Department of Natural Resources compiled information on barite in that province. Felderhof (1978), of the Nova Scotia Department of Mines, compiled a report on the three minerals in Nova Scotia. McArthur (1973), of the Newfoundland Department of Mines and Energy, Mineral Development Division, compiled a report on the occurrence of celestite and barite in Newfoundland.

Present Work

This study began in 1972. Field work, conducted in 1973, 1974, 1975 and 1976, included visits to past and present producers in Ontario, New Brunswick, Nova Scotia, Newfoundland, British Columbia and Yukon Territory. Visits were made to residual barite deposits in Washington County, Missouri and bedded barite deposits at Battle Mountain, Nevada and Stevens Country, Washington State. Information was collected from federal, provincial and scientific publications on 733 mineralized locations across Canada. This information was compiled in a computerized databank (see Appendix A) and deposits having some economic interest are tabulated by geographical location (Table 32) and by name (Table 33) and by chemical composition (Table 34).

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[1] Now Canada Centre for Mineral and Energy Technology (CANMET) of the Department of Energy, Mines and Resources.

[2] Now Mineral Policy Sector of the Department of Energy, Mines and Resources.

[3] Canadian Minerals Yearbook.

The libraries of the Geological Survey of Canada, CANMET and the CAN/SDI service of the Canada Institute for Scientific and Technical Information (CISTI) was the source of much of the Canadian and foreign literature consulted during the project. The CISTI library was used during the project for less accessible papers mainly in foreign language publications. Reference to numerous foreign publications has been made in preparing this report. Most of these are American and they include reports by federal and various state governments, scientific periodicals and text books.

American publications provide descriptions of deposit types in the United States that have not been identified in Canada. These include the Mississippi Valley residual, bedded and evaporite deposit-types. The Mississippi Valley deposits of central Missouri have been a source of barite and base metals. The residual barite has been mined in a belt extending eastward from southeast Missouri. Residual fluorite was mined from the regolith above fluorite – base metal veins in Cave in Rock and Rosiclare, Kentucky-Illinois. Barite is presently produced from bedded deposits in Montana and was formerly produced from similar deposits in northwest Washington State. Celestite was produced from evaporite deposits in California. A report by Shawe et al. (1976) provided much useful information, including an extensive bibliography on fluorite.

Other foreign publications consulted contain useful accounts of deposits in Great Britain, Germany, Japan, USSR and Iran. In particular, those by Collins (1972), Notholt and Highley (1971) and Thomas (1973) provide useful documentation of the sources and supply patterns within the United Kingdom. Translations of German papers were useful in connection with the subject of bedded barite associated with pyrite and black shales (Krebs, 1972; Gwosdz et al., 1974; Zimmerman, 1970). Japanese papers provide descriptions of the barite-bearing Kuroko massive sulphide deposits that are related to centres of volcanic activity (Aoki et al., 1970; Kajiwara, 1973; Lambert and Sato, 1974). Modern occurrences of celestite in the sabkha of Abu Dabi have been described by Evans and Shearman (1964) and discussions of the transportation and deposition of strontium by Vlasov (1966) are of interest.

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Historical Developments

Barium

Barite ($BaSO_4$), a mineral characterized by high specific gravity and thermal luminescence, was known in the early 17th century. In 1779 C.W. Scheele proved by a series of experiments that the element in barite having an insoluble sulphate was not calcium, as suspected, but an unknown element. The element was named barium from the Greek root barys (heavy). The same root in modified form is applied to the oxide baryta and the sulphate barytes (Hampel, 1968, p. 43). The naturally occurring carbonate of barium named witherite ($BaCO_3$) was first identified in 1784 by Dr. William Withering from specimens collected at the Anglezark mine, Lancashire. However, the new element was not isolated until 1808 when Humphrey Davy produced it from an amalgam by electrolysis of a soluble barium salt on a mercury cathode. Nels Nordenskiold in 1821 correlated the presence of barium with the green flame produced by burning barium salts.

Barium was identified in a variety of organisms. Scheele in 1771-1772 discovered barium in plant ashes and later suggested the use of barium nitrate as a precipitant for oxalic acid in analytical chemistry. J.G. Forchammer in 1865, found barium in the ashes of seaweed, sea shells, seawater and boiler scale of ocean going steamers. In 1909-1910 E.H.S. Bailey and D.L.E. Sayre detected barium in ashes of elder, ragweed, agrimony and other Kansas weeds. It is also present in trace amounts in many edible plants which draw barium from the rocks and soils beneath.

The history of exploration for barium in Canada began when the element was first reported (1863) in mineral waters, veins and replacement deposits in Ontario, Québec, Prince Edward Island and Nova Scotia. Barite-calcite-galena veins in marble were reported from Lansdowne Township and barite veins were reported from Dummer, Bathurst (31-69),[2] and MacNab Townships, Ontario; on Iron Island (31-134), Lake Nipissing, Ontario, and at Bruce Mines (41-03) Ontario. Barite veins were also reported along the Chaudière River and in the Templeton, Hull and Buckingham areas of Québec. Barite is associated with hematite, calcite, fluorite and feldspar in the Haycock iron mine (31-109), canton de Templeton, comté de Hull, Québec. The mineral was first mined in 1866 from the Eureka Mine (21-19) near Five Islands, Nova Scotia where about 7200 tonnes were extracted from irregular veins and pockets in argillite and limestone. The Brookfield, Nova Scotia deposit (11-05) was reported in 1868 and barite was recorded (1873) in the Acadia iron Mine (11-12) at Clifton and at Shubenacadie. Wood fossils in sandstone on Gallas Point (11-45), Prince Edward Island, are partly replaced by barite.

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[1] Now British Columbia University of Energy, Mines and Petroleum Resources

[2] The identification scheme for each Canadian location (See Appendix A) is a two-part sequence number consisting of the N.T.S. quadrangle number and sequence numbers for deposits in that quadrangle.

Between 1880 and 1900 barite was reported from British Columbia, and barite properties were developed in western and northern Ontario and on Cape Breton Island, Nova Scotia. Barite was reported in the Homestake Mine (82-45), near Adams Lake, British Columbia and in the copper veins of the Twin-J Mine, Vancouver Island (92-01) but no attempt was made to recover the mineral. The extensive search for silver in the Thunder Bay District of Ontario led to the first discovery of witherite in the Porcupine mine (52-25) and discovery of barite veins on Jarvis Island (52-03), South MacKellar (52-09) and Pie islands. The MacKellar vein (52-09) produced 9261 tonnes of barite between 1885 and 1894 and the Jarvis Island vein produced some silver but no barite. In eastern Ontario barite was reported on Iron Island (31-134), Lake Nipissing, and barytocelestite in Loughborough Township. In Nova Scotia veins were reported along Judique Chapel Brook (11-36), in Mabou Coalfield, and on MacMillan Point. None were of economic importance. Barite float was known along the east side of Lake Ainslie, Nova Scotia and several veins were identified in the hills east of the lake. The potential commercial value of this barite was, however, not recognized until late in the century when mining of it for use in paint manufacturing in Halifax and Montreal commenced in 1894 at Lake Ainslie.

The period between 1900 and World War II was characterized by sporadic production of small tonnages of barite for paint manufacture and fillers. During the war, partly as a result of the expiry of the patent held by the National Lead Company for barite-base drilling muds, coupled with increased demand for petroleum products, the Walton, Nova Scotia deposit was brought into production as a supplier for drilling muds. Small barite veins were also mined in northern Ontario in Penhorwood and Langmuir townships. Total production from northern Ontario did not exceed 907 tonnes (Guillet, 1963).

Since World War II Canadian barite production has come mainly from southeastern British Columbia, northern Ontario, Nova Scotia and Newfoundland. Production in British Columbia was initially from vein deposits near Invermere and subsequently the tailings ponds of the Mineral King (82-34) and Silver Giant (82-43) lead-zinc mines were reworked. A few thousand tonnes were mined from veins in northern Ontario. The Walton mine (21-13) in Nova Scotia, Canada's largest barite mine, produced more than 4 million tonnes between 1941 and its closure in 1978. New discoveries of bedded barite were made in the mid 1970s in northern British Columbia, Yukon Territory and District of Mackenzie. Of these, Rein (116-02), on the Dempster Highway, north of Dawson City; Cathy (105-34), 30 km north of Tea prospect; Tea Prospect (105-18), located 209 km northeast of Ross River, Yukon Territory and Mel-Jean (95-02), east of Watson Lake, have had surface stripping or drilling in preparation for eventual mining.

Strontium

Strontium is a fairly hard, silvery metal with chemical properties intermediate between those of calcium and barium. It was first identified in a non-metallic mineral collected from a lead mine near Strontian, Argylshire, Scotland (Weeks, 1966). Credit for the discovery is shared by Adair Crawford (1790) and William Cruikshank (1787). The mineral, now called strontianite, proved to be the carbonate of the metal strontium. The element was first isolated by Davy (1808) by electrolysis of a moist mixture of strontium hydroxide and chloride with mercuric oxide on a mercury cathode. In 1791 T.C. Hope reported on the brilliant red flame characteristically produced by the element and may have been the person to name the element "strontites" or "strontia". By a series of elaborate experiments, he showed that the salts – which resembled those of barium and calcium – were clearly those of a third new element. In 1799, G.S. Gibbes of Bath, England analyzed a crystalline material from Sodbury, Gloucestershire and identified it as the strontium sulphate, celestite. G. Moretti in 1812 discovered strontium in lavas and fossiliferous limestones. J.G. Forchammer discovered strontium along with barium in boiler scale from ocean-going steamers and in seaweed. In 1858, R. Bunsen produced a few grams of strontium by electrolysis. In 1910 M. Guntz and M. Gaillot isolated the pure metal from the oxide in the presence of aluminum in a vacuum retort.

Exploration for strontium in Canada commenced in 1851 when celestite was reported in Lansdowne Township, between Gananoque and Brockville, Ontario, and by the end of the century celestite, and less frequently strontianite, were reported in British Columbia and Nova Scotia. Pale green crusts and concretionary masses of strontianite were reported in 1894 in gravels and Tertiary shales along the Horsefly River (93-01), British Columbia. Celestite was reported in quarries near Kingston, Ontario and near Long Sault Rapids on the St. Lawrence River. In the course of a geological survey of Manitoulin Island, R. Bell reported celestite in fine grained, light bluish grey dolomitic limestone. Occurrences were reported on Cape Robert (41-02), Cape Bayard and Drummond Island. In 1889 celestite was reported in a vein cutting Grenville marble in Bagot Township and as reddish crystals lining cavities in limestone near the forks of the Credit River, Peel County, Ontario. Celestite was reported (1875) in a bed 30 cm thick in Carboniferous limestone on the right bank of Sydney River, Nova Scotia.

Since 1900, strontium minerals have been reported in British Columbia, Ontario, New Brunswick, Nova Scotia and Newfoundland (Table 35). Celestite was reported (1930) on the Rexspar property (82-50) near Birch Island, British Columbia in association with fluorite in a mineralized feldspar porphyry body. The celestite occurrence in Bagot Township, Ontario was named the Wilder Deposit (31-89) and a small quantity of the mineral was mined between 1918 and 1920. The Dorbeck deposit (21-31) near Memramcook, New Brunswick was identified and drilled during 1971. The Kaiser Celestite mine (11-28) was discovered, developed and mined between 1969 and 1976 at Lake Enon, Nova Scotia. Celestite was discovered in a few small bodies on the Ronan Property (12-05) and at Gillams Cove (12-06, -07) on Port au Port Peninsula, Newfoundland. These were drilled in 1942 and 1972 (McArthur, 1974).

Fluorine

The mineral fluorite has been used for decorative and utilitarian purposes since early historic time. The Greeks and Romans used the mineral in vases, drinking cups and table tops. The Chinese, as well as the American Indians, carved ornaments and figurines from large crystals. The use of the mineral as a metallurgical flux was reported by Agricola in 1594 (Weeks, 1966). The use of hydrofluoric acid in etching glass was practised as early as 1670 by H. Schwanhard even though it was not until 1771 that C.W. Scheele first isolated and identified the acid (Hampel, 1968). The first recorded production of hydrogen fluoride was in 1775 in England and it was first produced in the United States in 1820. Davy recognized the presence of a new element in 1813 but was unsuccessful in his attempts to isolate it. The new element was named fluorine by A. W. Ampere using the Latin root fluor (to flow). The element was first successfully isolated by Henri Moissan in 1893 by electrolysis of a mixture of anhydrous hydrogen fluoride and potassium fluoride. Early attempts to isolate the element were hampered by its corrosive nature, particularly at high temperatures, and the high cost of the apparatus required. The Moissan procedure, with slight modifications, is the commercial process presently used.

The development of industrial technology in this century has greatly increased the market for fluorite and encouraged the production of fluorsilicate byproducts of fertilizer manufacture. Between 1939 and 1945 apparatus was developed that permitted large volumes of commercial production of hydrogen fluoride and hydrofluoric acid as feedstocks for the rapidly growing fluorchemical industry. The development and widespread acceptance of open hearth steelmaking created an increased demand for fluorite that accelerated during World Wars I and II. The more recent changes to the B.O.P. (Basic Oxygen Proces) steelmaking process further enlarged the market for fluorite. The discovery of the inert fluorcarbons in 1931 and the use of hydrogen fluoride as a catalyst in the manufacture of alkalate, a vital component of high octane petroleum fuels, also increased the market. Beneficiation of fluorite ore progressed from belt-picking to froth flotation in 1920, through differential froth flotation in 1930 to heavy liquid procedures in 1940. Modern concentrates are often pelletized or briquetted to decrease wastage and increase efficiency in use. The development of the Hall electrolytic process to reduce alumina to aluminum created a large market for electrolyte cryolite. The main foreign source of cryolite, Ivigtut, Greenland was closed in 1962 after 100 years of operation (Grogan and Montgomery, 1975). Aluminum smelters have replaced natural cryolite with artificial cryolite manufactured from fluorite. As a result, the world market for fluorite continues to grow and the mineral is mined in most industrialized countries.

The history of exploration for fluorine in Canada began with the 1863 report of fluorite occurrences at localities in Ontario and Québec. Other localities were reported in those provinces and in British Columbia, Northwest Territories, New Brunswick, Nova Scotia, and Newfoundland by 1900. An occurrence was reported (1872) on Little Shuswap Lake, British Columbia. Fluorite was reported (1894) from Precambrian greenstones, Dubawnt River, 56 km west of Baker Lake, District of Keewatin. A number of occurrences were identified in Thunder Bay, Algoma, and Nipissing districts, Ontario. Those in Thunder Bay District include: Prince's mine (52-05); veins on the mainland opposite Pic Island (42-09); fluorite veins in syenite near MacKenzie River; Black Bay; Terrace Bay (42-11) and Fluor Island, Nipigon Bay. Other veins were reported in biotite granite near Blueberry Lake and fluorite was also reported in several silver veins near Thunder Bay. Fluorite was located east of Cape Gargantua and on an island near Cape Gravelly in Algoma District. Fluorite localities in Nipissing District include: Iron Island, Lake Nipissing (31-134); Ross Township (31-123, -124); and, cleavable masses of fluorite in pegmatite dykes, Cameron Township (31-135). Fluorite was reported (1899) at Marmora, Ontario (31-33) in iron ore and in veins hosted by marble, granite and limestone near Madoc (1873), Ontario. In Québec fluorite-bearing veins are found in comté de Gatineau; Baie St-Paul (21-49); La Malbaie, and the Québec City area (21-44). Fluorite is associated with hematite and barite in the Haycock mine (31-109), canton de Templeton, and with apatite-mica mineralization in the North Star Mine (31-128), Portland Township. Sites reported in New Brunswick include: Frye Island (21-06); Beech Hill (21-32); Westmorland County; Upham, Kings County; numerous small fluorite veins in Lower Carboniferous arkose at Harvey Settlement (21-26); and quartz-calcite-fluorite veins near Lister's Mills (21-27). Plaster and McNab coves, Nova Scotia were reported (1877) as sites of fluorite veins. Fluorite veins were also reported (1887) west of Great St. Lawrence Harbour, Newfoundland.

The discovery and development of Canadian fluorite deposits accelerated after the turn of this century. Discoveries were made and mines operated in British Columbia, Ontario and Newfoundland. The Rock Candy (82-09) fluorite veins, discovered in 1917 north of Grand Forks, British Columbia were brought into production in 1919 and mining continued for several years (Wilson, 1929; Ross, 1960). Fluorite production commenced in 1905 at Madoc, Ontario and 121 919 tonnes of metallurgical fluorspar were ultimately produced from 24 mines in the district before the last one closed in 1961 (Guillet, 1964). In the same period the Wilberforce area of Ontario also produced a small tonnage of fluorite (Guillet, 1964; Wilson, 1921). Production from mines at St. Lawrence, Newfoundland commenced in 1933 and terminated in 1978. In that period more than 3 000 000 tonnes of the mineral were produced. This district was Canada's largest fluorite producer.

Uses

Barite

Barite was produced primarily for use in paints until 1926 when the oil and gas industry greatly enlarged the market for the mineral as a result of increased exploration drilling. The mineral is used as an extender or filler in a variety of products, an additive in glass and ceramic products, and as a material for the construction industry. Probably the first use of barite was as an additive to lead-based paints. Both natural high quality white barite and acid-bleached barite are used as weighting agents or pigment extenders. As a pigment it is handicapped by its low index of refraction which reduces its capacity to cover blemishes. However, its low oil-absorption characteristic is an advantageous feature and the off-colour material can be used in coloured paints. Finely-ground barite either in its natural state or after bleaching by sulphuric acid has been used as an industrial filler, extender or weighting agent in rubber products, linoleum, plastics and in the paper industry in such products as bristol board, heavy printing paper and playing cards. Ground barite is also used as a surface finish in certain types of rope and in brake and clutch linings. Barite is used as a batch additive in the continuous tank production of glass because it homogenizes the melt and improves the brilliance and clarity of the finished product. Barite has also proven valuable in the production of barium titanite ceramics and in barium ferrite ceramic permanent magnets.

Since the discovery of the value of weighted drilling muds in the oil and gas industry, 80 to 90 per cent of the world's production of barite has been used for this purpose. Natural material having a specific gravity of 4.20 or greater can be used directly, whereas less pure barite can be beneficiated and used under suitable market conditions. The product is reduced to minus 325 mesh, and bagged or shipped in bulk to drilling sites. It is then combined with water and clay and circulated down the hole as drilling progresses. The mud seals and strengthens the borehole walls, lubricates the drill stem and cutting tool, lifts the cuttings to the surface and provides a heavy plug to reduce the risk of high pressure gas or oil blowouts.

The construction industry uses barite as an additive in concrete aggregate where high density is required, such as in heavy casings for oil and gas pipelines laid beneath the surface of swampy terrain. In atomic power installations the effectiveness of the mineral in adsorbing gamma radiation is utilized in poured concrete structures in lieu of the more expensive lead shielding. Recent studies have shown that asphalt mixtures that contain rubber and crushed barite make more durable surfaces for airport runways and parking lots. Barite mixtures are also used in ballasting large tires of construction equipment to facilitate impacting new fill sites.

Barite or witherite are feedstock for the production of barium carbonate and hydroxide as well as smaller amounts of other compounds. In total, such products have more than 2000 industrial uses, which can be grouped into 14 classes as follows:

CLASS	USE
Reagents and catalysts	Sugar refining
Sizing and coating	Waterproofing and fire-proofing
Filler materials	Textiles, papers
Manufacture of biochemicals	Vitamins, hormones, blood coagulents
Pyrotechnics	Production of green flames
Steel technology	Case hardened steel alloys
Pigment	Paints
Electrical products	For fluorescent lamps
Bonding agent	Bonding phosphors to glass in black and white TV tubes
Ore milling	Used as beneficiating agent in certain ores
Flux	Welding
Additives	Oils and greases
Smelting and refining	Magnesium, indium, zinc smelting and refining
Ceramics manufacture	Scum preventative in ceramic and brick manufacture
Filler, weighting agent	Plastics, rubber, textiles and papers
Agricultural chemicals	Insecticides, herbicides, and germicides

Barium metal is alloyed with aluminum, magnesium, lead and calcium in a variety of special alloys. The deoxidizing property of the element is utilized in TV and other vacuum tubes, where the ability of barium alloys to trap traces of gases significantly increases the electronic efficiency of such components.

Celestite

Celestite is used to produce a variety of strontium chemicals for a number of products and industrial uses that include pyrotechnic applications, glass and ceramics, metallurgy, fillers and pharmaceuticals (Fulton, 1975; Thomas, 1973). The first four applications use 80 to 90 per cent of world production.

Strontium carbonate, nitrate, peroxide, oxalate and formate are used in pyrotechnic devices. When burned these chemicals produce a brilliant crimson flame and for this reason they are used in red safety flares, fireworks and tracer ammunition. There are a variety of lighting applications, including the use of strontium chloride to produce phosphors for fluorescent and cathode ray tubes. Electrical applications include: combinations of strontium carbonate and iron oxide to form strontium ferrite ceramic magnets; strontium titanate, stannate and zirconate in electrical capacitors; and strontium nitrate in heating elements of thermionic valves.

Glass applications include the use of the carbonate in X-ray retardant glasses for cathode ray tube face plates. Strontium compounds are also used in the production of iridescent and other specialty glasses. Small amounts of strontium oxide are used in ceramic glazes and in some ceramics. Celestite has also been used as a filler and as a brightening and whitening agent in paints. Strontium sulphide is used in phosphorescent paints and more recently the chromate has been used in anti-corrosion primers for zinc, magnesium and aluminum alloys. Metallic strontium alloys are used to remove gas from vacuum tubes, as metallurgical scavengers to purify metals, and as a trace additive to increase the hardness and durability of lead and copper. Strontium carbonate is used in the production of high purity electrolytic zinc and strontium chromate is a reagent in the chrome-plating process. Strontium salicylate, bromide and iodide are used in a variety of pharmaceuticals. Celestite has a limited use as a filler in rubber, plastics and paints and in drilling muds. The use of celestite as a weighting agent in drilling muds ended in 1943 when the 20 year patent prohibition governing the use of barite in this application was removed.

A variety of minor applications include the use of strontium hydroxide in the Scheibler sugar refining process (1870-1914); the use of strontium carbonate as a welding rod coating; the removal of manganese and iron with strontium sulphate in the production of high purity caustic soda; and the use of stearate and napthanate as non-toxic stabilizers in PVC plastics. Strontium titanate crystals are used as artificial gemstones. Strontium, the product of celestite, cannot successfully be replaced by barium in X-ray reducing glasses, ferrite magnets or pyrotechnics.

Fluorite

The principal uses of fluorite are in the manufacture of hydrogen fluoride, as a metallurgical flux, in ceramic products and in a number of other industrial processes (Bartley, 1961; Notholt and Highley, 1971; Grogan and Montgomery, 1975). Anhydrous hydrogen fluoride is used in large amounts to manufacture synthetic cryolite, hydrofluoric acid, elemental fluorine, emulsified petrochemicals, and inorganic and organic fluorides.

Hydrogen fluoride (HF) is produced by reacting acid grade fluorspar[1] with sulphuric acid in a heated kiln. Part of the production is converted into hydrofluoric acid (70 per cent HF) for the manufacture of a variety of chemicals. The major part of the HF produced is used in the manufacture of synthetic cryolite, Na_3AlF_6 the electrolyte used in electrical pots to reduce alumina to aluminum metal. The reactions are as follows:

$$CaF_2 + H_2SO_4 = 2HF + CaSO_4:$$

Fluorspar is reacted with sulphuric acid to produce hydrogen fluoride and calcium sulphate.

$$6HF + NaAlO_2 + 2NaOH = Na_3AlF_6 + 4H_2O$$

Fluorspar is reacted with sodium meta-aluminate and sodium hydroxide to produce sodium fluoraluminate and water.

or

$$6HF + NaAlO_2 + Na_2CO_3 = Na_3AlF_6 + CO_2 + 3H_2O$$

Fluorspar is reacted with sodium meta-aluminate and sodium carbonate to produce sodium fluoraluminate, carbon dioxide, and water.

Hydrofluoric acid has an important use as a catalyst in the manufacture of alkalate, an ingredient in high octane fuel blends, in steel pickling, enamel stripping, glass etching and polishing and in electroplating operations.

Elemental fluorine is used in increasing amounts in the manufacture of uranium hexafluoride, sulphur hexafluoride and halogen fluorides. Gaseous uranium hexafluoride is used in the separation of ^{235}U from ^{238}U to provide enriched uranium fuels. Sulphur hexafluoride, a stable gas with high dielectric strength[1] is used in a variety of electrical applications. The chemically stable and inert halogen fluorides are used as substitutes for fluorine in several applications where greater ease of handling is desired.

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[1] **Fluorspar is the commercial name applied to fluorite concentrates.**

Inorganic fluorides are used in insecticides, preservatives, antiseptics, ceramic additives, electroplating solutions, fluxes, antioxidants, and as a trace additive to toothpaste. They are also used in the manufacture of the important catalyst boron trifluoride. Organic fluorides, the main product of the fluorine chemical industry, are fluorinated chlorocarbons and fluorocarbons. They are characterized by low toxicity and notable chemical stability and find application as refrigerants, aerosol propellants, and solvents as well as intermediate products in the manufacture of polymers such as fluorcarbon resins and elastomers. Since such resins are inert and have an unusually low coefficient of friction, they are useful in such applications as the manufacture of sealed bearings, window linkages in automobile doors and in chemical-resistant gaskets, valve parts and tank linings. Recently, the fluorinated chlorocarbons and fluorocarbons have generated environmental controversy because of the possibility that they may be damaging the ozone layer of the atmosphere. Perfluorchemicals (organic chemicals in which all hydrogen atoms have been replaced by fluorine) are being investigated in medical research as a possible substitute for blood.

The steel industry uses fluorite as a flux in open hearth furnaces, Basic Oxygen Furnaces and electric furnaces in amounts exceeding 9 kg per tonne of steel produced. The shift from open hearth to BOF (basic oxygen furnace) has tripled the amount of fluorspar required in the steelmaking process. Fluorite is also used for the same purpose and in similar amounts in cupola furnaces in steel and iron foundaries because of its action in increasing the fluidity of the slag and facilitating the movement of sulphur and phosphorus from the steel to the slag. The mineral is also used in the production of magnesium, calcium, zinc and manganese metals.

As much as three per cent ceramic grade fluorite is added to glass melts to make white or coloured opal glasses and 15 per cent to make opaque enamels. The glasses are used for a variety of containers and the enamels are applied to the steel parts of many household appliances. Lower grade fluorite concentrates are added to glass batches from which fiberglass is manufactured and to brick batches to control undesirable blemishes in the finished product. Other uses of fluorite include its application in electrical furnaces to manufacture calcium carbide and cyanamide for arc lamp electrodes and its use as the bonding agent in abrasive wheels.

Market specifications

Barite

Specifications for ground barite vary according to the end use of the material. The petroleum industry is the major user of barite as a weighting agent in drilling muds. The specifications usually call for a minimum specific gravity of 4.25, a 92 to 94 per cent barite content, a particle size of 90 to 95 per cent minus 325 mesh and a maximum content of 0.1 per cent water-soluble solids.

Barite products used in paint must contain 95 per cent barite, have a particle size at least minus 200 mesh, possess a high degree of whiteness and light reflectance and contain no more than 0.05 per cent Fe_2O_3, 0.2 per cent water-soluble materials, 0.5 per cent moisture and 2 per cent foreign material.

In general, glass specifications call for a minimum of 98 per cent barite, not more than 0.15 per cent Fe_2O_3 and only a trace of TiO_2. Some glass specifications require less than 1.5 per cent SiO_2 and 0.15 per cent Al_2O_3. The product should be ground to pass a 16 mesh screen and have between 5 and 40 per cent passing a 100 mesh screen. Finer material is undesirable because it tends to ball up in the melt. Next to that used in well drilling, barite used in the glass industry, including fiberglass and glass wool, accounts for the largest proportion of total Canadian consumption.

Specifications vary for crude barite used as a filler, extender or weighting agent in rubber or plastic goods, but the main factors are whiteness and particle size range. Most users prefer a minus 325 mesh product. In some requirements where weight is the critical factor the use of off-white material may be allowed.

Table 1A. General specifications for celestite for the manufacture of strontium carbonate and strontium nitrate

	For strontium carbonate	For strontium nitrate
Composition Limits %		
$SrSO_4$	>90 min.	>95 min.
$CaSO_4$	-	<1.5 max.
$BaSO_4$	<2 max.	<2 max.
F	<.1 max.	-
Maximum Particle size (cm)	15	-15,+.6

Source: Fulton, 1975, p. 1099.

Table 1B. General specifications of manufactured strontium carbonate made from celestite

	Glass Grade		Electronic Grade	
Composition	%		%	
$SrCO_3$	96	(min.)	96	(min.)
$BaCO_3$	3	(max.)	1.5	(max.)
$CaCO_3$	0.5	(max.)	-	
Total S (as SO_3)	0.4	(max.)	0.4	(max.)
Fe_2O_3	0.01	(max.)		
Na_2CO_3	1.0	(max.)	-	
Size specification (Tyler mesh)				
+ 10 mesh	0.0			
+ 14 mesh	2.0	(max.)		
+ 100 mesh	70-85			
+ 150 mesh	95	(min.)		
- 150 mesh	5	(max.)		

Source: Fulton, 1975, p. 1099.

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[1] "A dielectric is a material having electrical conductivity low in comparison to that of a metal. It is characterized by its dielectric constant and dielectric loss, both of which are functions of frequency and temperature" (Van Nostrand, 1976). SF_6 is chemically stable, an excellent insulator, has good electrical current interrupting properties, is non-flammable, non-toxic, colourless and inert.

Table 2. Celestite specifications for the United Kingdom and United States

	United Kingdom %	U.S. National Stockpile %	Zinc refining %
Composition			
$SrSO_4$	95 (min.)	96.0 (min.)	95 or less
$BaSO_4$	2.0 (max.)		
SiO_2	2.0 (max.)		
$CaCO_3$	0.5 (max.)		
Fe_2O_3	0.5 (max.)		
$CaSO_4$		2.0 (max.)	
Free Moisture content (%)		2.0 (max.)	

Source: Thomas, 1973, p. 12.

A variety of specifications exist governing the use of ground barite in chemicals, ceramic products, brake linings and heavy construction. In general, the chemical industry requires a 95 per cent barite content, not more than 1 to 2 percent Fe_2O_3, less than 1 per cent strontium sulphate and only trace amounts of fluorine. The particle size should lie between 4 and 20 mesh for efficient utilization. Barite used in heavy concrete aggregates is supplied at standard gravel or crushed stone sizes.

Celestite

Specifications for celestite for use in the manufacture of strontium carbonate and strontium nitrate are given in Table 1A. For use in the glass and electronics industries manufactured strontium carbonate (Table 1B) must have specific characteristics. Specifications for celestite required by industry in England, the United States National Stockpile and the zinc refining industry also differ in detail as shown in Table 2. In the paint industry, some manufacturers demand more stringent specifications, particularly in connection with the colour.

Fluorite

The bulk of fluorite concentrates are prepared to meet the requirements of three industrial processes: the manufacture of hydrogen fluoride and fluorine chemicals; the manufacture of ceramic materials; and, the metallurgical processing of metals such as steel and aluminum. Acid grade fluorite concentrates should in general contain not less than 97 per cent calcium fluoride, not more than 1 to 1.5 per cent silica and not more than 0.03 to 0.10 per cent sulphur as sulphide or free sulphur. Some buyers, however, will accept concentrates with slightly less than 97 per cent calcium fluoride for acid manufacture. Additional limits apply to the calcium carbonate content as well as to the moisture content, in general neither of these should exceed 0.1 per cent. Optimum particle size is important in order to maximize the rate of reaction with sulphuric acid and minimize dust losses.

Ceramic grade fluorite is marketed in two main classes of material. No. 1 grade customarily contains 95 to 96 per cent calcium fluoride, and No. 2 grade contains 85 to 95 per cent calcium fluoride. Some users, however, specify an intermediate grade carrying 93 to 94 per cent calcium fluoride. The specifications may call for less than 2.5 to 3.0 per cent silica, minor calcite, not over 0.12 per cent ferric oxide and only traces of lead and zinc sulphates. In general most users have customized specifications that are met by the supplier.

The United States metallurgical grade fluorite contains a minimum of 60 "effective"[1] per cent calcium fluoride, generally less than 0.30 per cent sulphur as sulphide and less than 0.25 to 0.50 per cent lead. The lump- or gravel- spar product should be sized to pass 2.5 to 3.75 cm screens and contain less than 15 per cent sized to pass a 1.6 cm screen. Outside the United States metallurgical fluorite concentrates can contain a minimum of 80 per cent calcium fluoride and a maximum of 15 per cent silica. Briquettes and pellets are made of fluorite fines and these have physical and chemical properties that are especially suitable in the BOP steelmaking process.

World Production

Barite

World production of barite in 1981 (including the Communist block countries) was estimated at 7.8 million t in comparison with 6.7 million t in 1979 (Table 3). More than 80 to 90 per cent of production was consumed in oil and gas well drilling operations. Dependence on the drilling industry as the principal market means that demand is subject to geographical shifts as exploration for oil and gas moves into new areas. The low value and heavy weight of barite concentrates make production and transportation costs and tariffs, and import and export controls, critical factors in the profitable operation of a barite mine. Consequently, new sources of barite are usually sought close to markets, leading to a geographically widely dispersed production base. On a global basis there is widespread production of barite and a considerable international trade in the commodity (Brobst, 1958, 1973). This can be illustrated by the following quotes from Castelli (1981).

"World barite production in 1980 is estimated to have been 8.1 million st, (7.29 million t)[2] an increase of 9.6% from 1979."

"US production continued to be strong because of US ore's lower price. China became the largest supplier of barite imported by the US in 1980 and appears to have sufficient reserves to continue exporting at a high rate."

Estimated US mine production was a 28% increase over 1979 and 23% over 1978s 2,112,000 st, (1.90 million t) the previous record."

"Nevada continued to be the largest US producer with 85% of the total, followed by Missouri with 4%. Other producing states were Alaska, Arkansas, California, Georgia, Idaho, Illinois, Montana, New Mexico and Tennessee."

"US imports are estimated to have increased from 1,489,000 st (1.34 million t) in 1979 to 2,000,000 st (1.8 million t) in 1980. The leading sources during the first nine months of 1980 China (25.6%), Peru (16.9%), Chile (10.4%), India (10.2%), Morocco (9.7%) and Thailand (8.2%)."

The drilling mud market continues to consume about 90 per cent of total barite supply. Other markets – paint, glass, rubber, and barium chemicals – show very little change in usage.

In Canadian developments barite was mined in British Columbia and Ontario. The construction of a road from the north Canol Highway to the Tea stratiform barite deposits southwest of Macmillan Pass, Yukon Territory was completed in 1978. No production has yet (1983) occurred.

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[1] "effective" per cent is calculated by multiplying the silica per cent by 2.5 and subtracting the product from the calcium fluoride content: For example a concentrate having 85 per cent calcium fluoride and 6 per cent silica would calculate to 70 "effective" per cent calcium fluoride.

[2] metric conversions by the author.

Table 3. World barite production, 1979-81 and reserves 1981

Countries	Mine Production (000 t) 1979	1980	1981e/	Reserves (000 t) 1981e/
United States	1843	2036	2177	49885
Canada	67	91	91	14500
China (mainland)		680	771	9070
France	226	226	226	5442
German Federal Republic	161	145	136	5442
Ireland	362	317	317	8160
Italy	215	226	226	5442
Mexico	151	272	317	9070
Morocco	230	317	272	2720
Peru	362	272	317	6350
Thailand	378	299	226	9070
Yugoslavia	54	45	45	2720
Other Market Economy Countries	934	1161	1088	19950
Central Economy Countries e/	1329	426	454	9070
	1329	7586	7754	198633

e/ estimate

Source: U.S. Bureau of Mines; Mineral Commodity Summaries; 1981, p. 15; 1982, p. 15.

Abitibi Price-Asarco added a barite circuit to its base metal flotation mill at Buchans, Newfoundland. This commenced operation in 1981 on a seasonal basis.

The number of barite grinding mills and production capacity of continental United States was greatly increased in 1980. New mines or reopened mines include the Old Spanish Mine, Nevada County, California; and in Nevada the Miller, Red House and Stormy Creek barite mines were readied for production.

In Mexico barite mining operations were enlarged at Barita de Sonora, Minerales de Barita in Michoacan and Minera Capela Sa de CV. The last company also plans to recover barite from tailings of a lead-zinc sulphide flotation plant (Castelli, 1981).

Production of barite in Ireland has been augmented by additional capacity for Milchem (U.K.) Ltd., Magcobar (Ireland) Ltd., and Horace Taylor Minerals Limited.

A new company in France, Société des Mines Gorrot-Chaillac, was formed to work the Rossignol barite deposit 30 km south of Chateauroux. Resources there are estimated to be about 8.8 million tonnes. A plant to produce 100 000 tonnes per year by heavy media separation was in production in 1977 (Stevens, 1977).

The Government of India in 1976 announced that all exports of barite would be channelled through the government owned Minerals and Metals Trading Corp. (MMTC), a step designed to control exports and to obtain a higher price for barite. The government has also reported a large deposit of barite with reserves of 15 000 000 tonnes in Margarupeta, State of Andra Pradesh.

China's annual production is estimated to exceed 170 000 tonnes and increased drilling over the past few years has undoubtedly increased domestic demand for barite. The increase in offshore drilling on the India-Pakistan shelf will result in larger markets for production in India and Pakistan.

The recent increase in drilling activity in Indonesia and the Philippines will lead to barite exploration and development of mines in Australia. Construction and modification of mills to increase efficiency and production have been announced for Algeria, Australia, Iran, Ireland, and Thailand.

Table 4. World celestite production, 1979-1981

Countries	Mine production tonnes 1979	1980	1981e/
Algeria	2558	2358	2358
Argentina	726		
Iran	3628	2268	2268
Mexico	18503	13152	17687
Spain	14566	8163	9977
Turkey	7982	3991	4354
United Kingdom	1887	2177	2268
Other market economy countries	925	907	1088
Controlled economy countries	907	907	907
World Totals	51682	33923	40907

e/ estimates

Source: U.S. Bureau of Mines, Mineral Commodity Summary, 1981, p. 153; 1982, p. 149.

Celestite

Celestite is a major source, and strontianite a minor source of strontium. Celestite is mined in several countries (Table 4) but there is a limited demand (40 000 to 50 000 tonnes per year) and the market is restricted mainly to the U.S.S.R., Europe, United States and Japan. World consumption grew from 5000 tonnes per year in 1920 to 40 907 tonnes per year in 1981, with sharp fluctuations upwards in times of major wars because of the use of strontium chemicals in pyrotechnical devices and ammunition. World reserves are known to be large although details regarding location, tonnage and grade are lacking. The nature of the demand for strontium in the world market does not encourage the publication of these data. Technological advances in non-military products such as glass for TV tubes, special lubricants and electronic equipment have not led to the anticipated major growth in demand.

The Yate area, Gloucestershire, England was the source of 90 per cent of the celestite produced between 1840 and World War II. During World War II inflated demand for strontium chemicals resulted in production from new mines in Spain and Mexico and by the late 1960s their output had exceeded United Kingdom production. The higher grade, and lower cost material from Spain and Mexico made the British source unprofitable and the Yate operation was closed in September 1974 but re-opened again in 1976.

Mexican celestite deposits have been known for many years but exploitation began only in 1941 in response to wartime needs. Production first came from celestite veins in the Providencia gold-silver mine near Matehuala, San Luis Potosi State. Later the San Augustin mine, Coahuila State was developed for celestite alone. The latter product is low cost, reserves are large and it has the advantage of proximity to the large American market.

The main centre of Spanish production is Montevive, southwest of Granada. The celestite is mined by open pit methods from flat lying sedimentary rocks consisting of limestone, clays and gypsum. Proven reserves are reported to be 2 million tonnes. Contaminants include barite, anhydrite, silica and alumina but the product is free of deleterious metallic minerals.

Canadian celestite production has been limited to the Wilder property (31-89) near Calabogie, Ontario and the Kaiser Mine (11-28) on Cape Breton Island, Nova Scotia. The former produced less than 1000 tonnes many years ago. The latter came into production in 1969 and ceased operation in December 1976 because of high production costs and poor market conditions. The Kaiser Celestite Mine was operated from open pits exploiting stratiform celestite-bearing mantos hosted by Mississippian limestone. Significant reserves of celestite remain in the deposit.

Fluorite

Fluorite and, increasingly, fluorapatite are the major sources of fluorine. Fluorite is mined in many countries (see Table 5) and the byproduct, fluorosilicate, is recovered from chemical fertilizer plants processing ores from sedimentary phosphorite beds in southeastern United States. World production of 4.94 million tonnes in 1981 is little changed from 1979. Increased demand caused by technological changes in the steel, chemical and aluminum industries, coupled with slow development of new reserves, caused a brief flurry of exploration in the late 1960s. New reserves were found but exploration declined as the demand for fluorite declined. This is attributed to the slowdown of the economy as fuel prices rose and demand for aluminum and steel products slowed. Consequently demand in the early 1970s was largely met through withdrawals from national stockpiles. In 1981 the demand for fluorite declined 12 per cent from 1980 for several reasons. The steel mills were producing less steel; the primary aluminum smelters were producing less aluminum and they were recovering more fluorine for re-use. The ban of the use of fluorcarbons compounds as aerosol propellants and the high cost of fluorite concentrates also contributed to the declining demand. However, the demand for fluorite briquettes and acid grade concentrates remained strong.

Mexico ranks as the world's largest supplier of fluorite, accounting for about 25 per cent of world production. Mining commenced in Mexico prior to World War I and was greatly expanded during World War II. Most production comes from underground mines in the Zaragoza area, San Luis Postosi State. Proximity to the large American market has made Mexico the main supplier to the United States. Policy on sales and prices is set by the Mexican Fluorspar Institute, a producer organization, however fluorite production in Mexico is increasingly being influenced by national policies requiring diminished exports of crude concentrates.

Table 5. World fluorite production, 1979-1981 and reserves 1981

Countries	Mine production (000 t) 1979	1980	1981e/	Reserves (000 t) 1981e/
United States	99	84	104	106119
China - mainland	399	408	408	14512
France	317	290	272	21768
German Federal Republic		370	362	45350
Italy	176	150	136	19047
Kenya	100	91	91	13605
Mexico	875	907	907	61674
Mongolia e/	408	444	444	9070
South Africa, Rep. of	453	499	499	154190
Spain	408	340	362	13605
Thailand	181	172	181	19047
United Kingdom	183	118	109	19024
USSR	522	522	522	217680
Other market economy countries	408	249	272	70746
Central Economy Countries	258	258	272	6349
	4787	4902	4941	695667

e/ estimate

Source: U.S. Bureau of Mines, Mineral Commodity Summary; 1981, p. 51; 1982, p. 51.

Table 6. Canadian barite production, trade and consumption, 1979-81

	1979 tonnes	1980 tonnes	1981p tonnes
Imports			
(United States)	8389	44930	10962
Ireland	NA	NA	5000
Netherlands	NA	54	254
United Kingdom	9	NA	NA
Other	NA	173	62
	8398	45157	16278
Exports			
United States	2038	645	405
Consumption			
Well drilling	91992	135359	NA
Rubber goods	1058	915	NA
Paint and varnish	2440	1567	NA
Glass and glass products	7	121	NA
Other*	818	867	NA
	96315	138829	

Source: Statistics Canada; Mineral Policy Sector, Department of Energy Mines and Resources.

NA = data not available.

p = preliminary.

*Consumption in a variety of other products and processes.

The United States is the world's largest consumer of fluorite concentrates, the amount being 1 228 000 tonnes (1981) U.S. Bureau of Mines in 1978. Approximately 905 000 tonnes of fluorite concentrates were imported (1981) and the remainder was provided from deposits in the Illinois-Kentucky district and to a lesser degree from deposits in Montana, Colorado, Idaho, Arizona, New Mexico and Utah. Recently additional domestic capacity has been developed from deposits near Salem, Kentucky, at Teller, Alaska and at Sweetwater, Tennessee. Mexico continues to be the main foreign source of United States fluorspar supplies.

The U.S.S.R., the world's second largest producer of fluorite concentrates at 550 000 tonnes, imports another 500 000 tonnes from sources in satellite countries to meet domestic requirements. The People's Republic of China produced 726 000 tonnes (1978) in China and Mongolia for domestic use and for export.

Spain produced 408 000 tonnes of fluorite concentrates in 1978 with a large proportion of production being exported to the United States and West Germany. New reserves have recently been found in the Caravia district in Oviedo Province of Spain.

Italy, France and the United Kingdom produced more than 90 700 tonnes (1978) each.

Thailand is one of the largest producers of fluorite concentrates in southeast Asia, with production being shipped mainly to Japan. Deposits containing reported reserves of 21 million tonnes (1981) grading 60 per cent fluorite are being developed (1979) on the upper reaches of the River Kwai. Difficult and costly transportation problems coupled with primitive conditions in the region are limiting factors in the development of these deposits.

In Africa, output of fluorite comes mainly from South Africa which is reported to have 25 per cent of the world's known reserves. Namibia (formerly South West Africa), Kenya, Tunisia and Morocco are also significant producers.

Canadian Consumption

Barite

Canadian consumption of barite in 1980 was estimated at 138 829 tonnes, 90 per cent of which was consumed by the oil and gas drilling industry (Table 6). Less than 10 per cent is consumed in varnish and paints and less than 5 per cent in glass and glass products, rubber goods and unspecified products. Canada imported 45 157 tonnes (1980) from the United States (Table 6).

Celestite

Canada's minor requirements for celestite are mainly satisfied by imports from the United States. Because demand is so small, celestite import data are not recorded.

Fluorite

In 1979 Canada imported 167 904 tonnes and consumed 107 004 tonnes of fluorite (Table 7). This was used mainly as a metallurgical flux and to a lesser degree in the chemical industries. Smaller amounts were consumed in the petroleum refining industry and in several other industries.

GEOCHEMISTRY AND MINERALOGY

General Comments

Barium and strontium are members of the Alkaline Earth Metal Group (Group IIA) whereas fluorine is a gaseous member of the Halogen Group (Group VIIA) of the Periodic Table. All three elements are strongly lithophile in the crust; fluorine is the only one of the three that has been reported in the atmosphere. They are known to accumulate in coal and oil, and in both modern and fossil plants and animals. Neither barium nor strontium are known to have any physiological function to perform in living tissue but fluorine improves the durability of human tooth enamel. Barium in the biosphere is moderately toxic for plants and slightly toxic for animals. Fluorine in excess of 1 ppm in natural waters is toxic to humans and animals (fluorosis).

Barium

Geochemistry

Barium, the twenty-first most abundant element in the lithosphere (Table 9), is a soft, silvery-white metal that resembles lead. The specific gravity is 3.5 (20°C) and the melting point is 725°C. Several other chemical properties are tabulated in Table 8. The element occurs mainly in the mineral barite ($BaSO_4$), which has been synthesized by Blount (1974).

Ba^{2+} in the crystal structure of barium minerals is surrounded by O^{2-}, OH^- and H_2O or a halogen anion as nearest neighbors. The bond-type is predominantly ionic.

Table 7. Canadian fluorite production, trade and consumption, 1978-80

	1978 (tonnes)	1979 (tonnes)	1980e/ (tonnes)
Production (mine shipments)	-[3]		
Imports			
Mexico	109 236	105 862	108 962
United States	9 112	19 203	17 752
Spain	9 680		8 599
Morocco	12 458	13 417	39 008
South Africa	29 250	21 006	27 507
United Kingdom			21 311
Other countries		8 416	
Totals	169 736	167 904	223 139
Consumption (available data)[1]			
Metallurigical flux	30 880	31 281	
Foundaries	15 657	11 722	
Other[2]	81 743	64 001	
Totals	128 280	107 004	

Source: Statistics Canada; Mineral Policy Sector, Department of Energy, Mines and Resources.

e/estimate;

[1] Reported by consumers;

[2] Includes use in production of aluminum and chemicals, petroleum refining and other miscellaneous uses: Blanks indicate data not available.

[3] Canada's only fluorite mine operated at St. Lawrence, Nfld., by ALCAN, closed in 1978.

Table 8. Physical and chemical properties of barium, strontium, fluorine and related elements

Element	Atomic[1] number	Atomic[1] weight	Group No.[1] (Periodic Table)	Ionic crystal[2] radius Angstrom units	Electro-[1] negativity	Ionic potential Kcal/g atom
Ba^{2+}	56	137.34	II-A	1.38	0.9	1.5
O^{2-}	8	15.9994	VI-A	1.40	3.4	
K^{+}	19	39.102	I-A	1.33	0.8	0.75
OH^{-}				1.33		
F^{-}	9	18.9984	VII-A	1.36	4.0	101.8
Sr^{2+}	38	87.62	II-A	1.18	1.0	1.8
Ca^{2+}	20	40.08	II-A	1.06	1.0	2.0
Mg^{2+}	12	24.312	II-A	0.75	1.3	3.0

Source. [1] Hampel, 1968, p. 201; [2] Van Nostrand, 1976, p. 509.

Barium is the largest divalent cation except for Ra^{2+} and it replaces or is replaced isostructurally by other large cations such as Pb^{2+} and Sr^{2+}. Less commonly it replaces K^{+} and the smaller cation Ca^{2+}. Barite forms a more or less continuous isomorphous solid solution series with Ca, Sr, Ra and Pb sulphates that includes angleso-barite, baryto-celestite and calcio-barite. In the carbonate minerals Ba^{2+} replaces Ca^{2+} in members of the aragonite series. Naturally-occurring barium borate minerals have not been described, although a few such compounds have been synthesized.

Barium occurs in the crystal lattices of several silicate minerals, chiefly substituting for potassium in feldspars and micas. It is concentrated in the early-crystallized feldspars and micas relative to products of the later stages of magmatic crystallization. The element occurs in the celsian (Ba-feldspar) molecule present in trace to minor amounts in most potash feldspars. Less commonly Ba^{2+} substitutes for Ca^{2+} in the structures of rock-forming silicates (plagioclase, pyroxene, mica and amphibole), phosphates (apatite) and carbonates (calcite). Most of the barium-bearing silicate minerals are structurally complex and include chain silicates, sheet silicates and tectosilicates. Generally, barium occurs as a dispersed element in many igneous rocks although only rarely as a primary independent mineral. Carbonatites are an exception (Table 9).

Barium occurs in a variety of unconsolidated and consolidated clastic sedimentary rocks, including deep sea, shallow-water and terrestrial sediments (Table 9) (Arrhenius, 1963; Arrhenius and Bonatti, 1965). For example, deep sea clays average 750 ppm barium in the Atlantic and 4000 ppm in the Pacific basin (Puchelt, 1972). Barium-rich areas commonly underlie zones of intense biological activity or occur near oceanic ridges where the element may have been contributed from volcanic sources. Barium in an abyssal environment may be adsorbed on clays, manganese oxides or the zeolite mineral phillipsite. Thus manganese nodules are often enriched in the element. On the other hand, deep sea carbonates consisting of Globigerina or Foraminifera tests are relatively low in barium, particularly where the carbonate content is high. In nearshore or shelf environments, clastic detritus from streams combined with that from offshore reefs commonly produce sediments enriched in barium. On land, residual soils, such as those in central United States, may contain economic concentrations of barite. Recent placers and lag gravels in the Cordillera of western Canada are locally characterized by fine- to coarse-grained clastic fragments of barite mechanically weathered from the bedrock and transported by streams to new sites. Poorly consolidated sands and gravels such as the Pike gravel of Dierks District, west-central Arkansas contain anomalous amounts of barite (Scull, 1958). Here, barium was precipitated either as intergranular barite cement or as rosettes of coarse crystals with numerous inclusions of detrital quartz (Ham and Merritt, 1944). Precipitation took place where barium-bearing groundwater encountered supplies of sulphate anions.

Sedimentary rocks formed through chemical processes are also commonly enriched in barium. These are illustrated by the high-grade baritites off the Florida coast and baritite in the Devonian rocks at the headwaters of Sulphur Creek, British Columbia (Morrow et al., 1976). This type of occurrence is attributed to barium-bearing brines, in modern aquifers and paleoaquifers respectively, that discharged into a submarine environment. Barium was supplied to interstitial waters by the conversion of barian aragonite to calcite or to dolomite. Barite precipitates at points where the barium-rich interstitial water mixes with sulphate-bearing seawater.

Barium minerals rarely occur in regionally metamorphosed rocks except for marble and calcsilicate rocks (e.g. at Clyde Forks, 31-08, Ont). In addition, the typical metamorphic minerals, sillimanite, staurolite, and garnet do not accommodate barium in their lattices. Barite does occur in epigenetic veins cutting a variety of metamorphic host rocks. Barium distribution and abundance in metamorphic rocks (Table 9) have not been extensively studied, although preliminary studies on the distribution of Ba have been made in regionally metamorphosed rocks, including eclogite, skarns, greisens and metasomatic products (Puchelt, 1972). In general, barium concentrations vary widely for each rock type so that average compositions may have little significance. Metamorphic rocks such as eclogites, may be exceptional because they are barium-poor. Some skarns may show trends in barium content with Ba increasing with metamorphic grade and decreasing under the effects of retrograde metamorphism. Greisens generally have less barium than the rocks from which they were derived, but the converse is true for metasomatites related to some granite intrusions.

Weathering Processes

Barium, as a result of weathering processes, is either dissolved from independent barium minerals and from barium-bearing silicate minerals or remains undissolved in a residual soil derived from decomposed wall rocks. In the first case, chemical and biological processes, including the activity of anaerobic bacteria (Bolze et al., 1974), take the element into aqueous solution as the bicarbonate or chloride. This process may be promoted by the presence of an electrolyte such as (NaCl) in the groundwater. Barium is then transported as ions in solution and adsorbed on particles of clay, iron, or manganese hydrosols or organic debris. Barium precipitates as barite when sulphate anions are encountered. Sulphate anions could, for example, have their source in evaporite beds, volcanic emanations, a buried intrusion, organic material or seawater.

In the case of residual soils, long periods of weathering reduce barite-bearing sedimentary rocks to clays, silts and sands in which the barite persists. For example, the porous, algal reef-bearing Eminence and Potosi dolomites of

Table 9. Abundance of barium, strontium and fluorine in the lithosphere and in a variety of rock types

	Vinogradov (1956)	Puchelt (1972)	Brobst (1973)	Vinogradov (1956)	Peterman and Hedge (1972)	Vinogradov (1956)	Koritnig (1972)	Boyle (1976)
	Ba ppm	Ba ppm	Ba ppm	Sr ppm	Sr ppm	F ppm	F ppm	F ppm
LITHOSPHERE								
Ultramafic rocks	15			27		110		
Mafic rocks	270			440		370		
Intermediate rocks	650			800		500		
Felsic rocks	830			300		800		
Clay & shales	800			450		500		
EXTRUSIVE ROCKS								
Basalt		246-613	360		200			375
Andesite		703	210		400			350
Rhyolite		1127	480					610
Phonolite		999	930		500 -1200			950
INTRUSIVE ROCKS								
Gabbro, diabase		246	420		200			420
Granite & granodiorite		732						
Granodiorite		811-888	870		100			810
Carbonatite		3799						8100
Diorite		714						665
Pegmatite								4320
SEDIMENTARY ROCKS								
Sandstone		316	180				200	180
Shale		546	800		220		650	790
Oceanic sediments		750-4000	730					640
Limestone		-200	220		425 -765		200	220
Dolomite			260					260
Carbonate rocks		90						
Phosphate rocks								30500
Soils			285					
REGIONALLY METAMORPHOSED ROCKS								
Metagabbro								120
Schist								250
Amphibolite								740
Hornblende hybrid								650
Gneiss								1030
METASOMATIC ROCKS								
Hornfels								1630
Skarn (regional)								1200
Skarn (contact)								9780
Kaolinized granite								2800
Fenites								400

Washington County, Missouri have been reduced to soils in which residual barite and drusy quartz persist. Barite in this instance has the form and distribution of disaggregated veins, lenses and solution cavity fillings that resemble those still in place in the underlying unweathered dolomites. Groundwater action responsible for these residual deposits resulted in mechanical release of barite and quartz but the two minerals remained undissolved. This style of weathering has produced large commercial deposits of barite in a belt extending eastward from Missouri to the Atlantic coast. A similar process of weathering of bedrock gneisses, schists and baritic carbonate rocks has produced the baritiferous placer sands and lag gravels of the Yukon Territory and northern British Columbia.

Biogeochemistry

Fossil Fuels

Barium is in many cases accumulated by fossil fuels. For example, the element is locally enriched in peat deposits, and formation waters in some English coal measures contain recoverable amounts of barium chloride.

Marine Plants

Barium distribution in marine plants has not been studied extensively although Ba is present in such plants. The hard and soft parts of some coccoliths, diatoms and algae accumulate barium and may thereby contribute to the anomalous barite contents of some fossiliferous sedimentary rocks.

Marine Animals

Marine animals are a likely factor in the concentrations of barium in black shale-baritite assemblages and bedded siliceous argillite-baritite deposits. Some authors relate the high barium content of pelagic sediments to biological activity (Revelle et al., 1955; Chow and Goldberg, 1960; Brongersma-Sanders, 1966). Modern pelagic sediments tend to be barium-rich, as for example those being deposited on the East Pacific Rise, the east side of equatorial Atlantic Ocean and the Black Sea. In these areas barium is extracted from seawater and accumulated in the tissues and skeletons of living plankton. The dead organisms settle into deeper water carrying barium that is eventually incorporated in the pelagic sediments. During this process, delicate skeletons are dissolved in seawater and the barium continues downward as crystals – in solution, in fecal pellets or trapped in tissues. The barium-accumulating species are often characterized by delicate skeletons and thus fossil evidence is sparse or lacking in the resulting barium-rich sediments. During summer the surface waters of the Black Sea have a large population of the diatoms **Chaetoceros curvisetus** and **Rhizosolenia calcar avis** both of which extract anomalous amounts of barium from the seawater. If barium has accumulated in siliceous skeletons rather than in the soft parts, the probability increases that the element will reach the pelagic sediments beneath. Recent freshwater and brackish water molluscs, e.g. **Cardium edule** also accumulate barium, and certain nonmarine fossil counterparts exhibit a higher barium content than do recent species. However, the accumulation of barium in molluscs does not appear to have been as effective a process as the scavenging effects of various delicate floating marine animals.

Bacteria

Black siliceous oozes or clays accumulate barium in anaerobic environments inhabited by sulphate-reducing bacteria. The latter live on the organic debris, attack clastic or diagenetic barite, reduce the sulphate to sulphide and freed the barium goes into solution as part of the diagenetic process (Bolze et al., 1974). The sulphide ion combines with available iron to form marcasite or pyrite and the soluble barium recombines with sulphate when a new supply of the cation is encountered. Modern sulphate-reducing bacteria have been identified and their fatty acids correspond with those extracted from middle Palaeozoic black shales (Miller et al., 1972). The preservation of amorphous carbon and iron sulphides together with petrographic and textural evidence support the conclusion that this process contributed to the formation of interbedded baritites and black shales.

Mineralogy

More than 80 natural barium-bearing minerals have been identified (Fleischer, 1975; Palache et al., 1951; Fischer, 1972a) and many times that number of artificial compounds of the element have been synthesized (J.C.P.D.S., 1976)[1]. However, only a few of the naturally occurring minerals, including barite and witherite, have been thoroughly studied. The characteristics of the more common barite minerals are summarized in Table 10.

Barium-bearing minerals include oxides, carbonates, nitrates, sulphates, selenites, phosphates, arsenates, vanadates and silicates, but only a few contain barium as a major constituent. Seven oxides contain minor to trace amounts of barium but only psilomelane, an ore mineral of manganese, is widespread enough to have potential economic interest. Twelve barium-bearing carbonate minerals occur, but only witherite has been a commercial source of the element and barytocalcite is a possible source. The barium-bearing nitrate, sulphate and selenite minerals include: nitrobarite, barite and guilleminite respectively. Of the 17 barium-bearing phosphate, arsenate and vanadate minerals, few are well known and none have commercial significance (Fischer, 1972a).

Barium-rich minerals are characterized by higher specific gravities than most nonmetallic minerals, ranging from 3 to 4.95 (Table 10). Hardnesses range from two to seven and colours are similarly variable, from colourless to black in the case of the metallic oxides. Colours for some species (e.g. barite) are the result of contaminants (ochre, clay, amorphous carbon, petroleum, etc.). Most barium minerals are transparent and a few are opaque.

Strontium

Geochemistry

Strontium, the 22nd most abundant element in the lithosphere (See Table 9), is a silvery-white, light metallic and ductile metal which is a good conductor of heat and electricity (Peterman and Hedge, 1972; Vlasov, 1966), (see Table 8). It has a density of 2.59, hardness of 1.8, melting point 752-797°C, electrical conductivity of 4 and is chemically, highly active. The element is a mixture of four natural isotopes: ^{88}Sr (82.75%), ^{86}Sr (9.75%), ^{87}Sr (6.96%) and ^{84}Sr (0.55%). Several synthetic isotopes have been prepared of which ^{90}Sr is the best known because it is present in radioactive fallout. The isotope abundances are useful both as a radioactive clock and as a provenance indicator.

The most common strontium minerals are celestite ($SrSO_4$) and strontianite ($SrCO_3$). Strontium ions have a valency of 2+ and are commonly bound to O^{2-}, OH^- and H_2O. Because it has an ionic radius between those of Ca and Ba and somewhat less than those of K^+ and Pb^+, Sr can replace, or be replaced by, any of the four elements. Strontium is found in two mineral series: the sulphates (celestite, barite, anglesite and barytocelestite) and the carbonates (strontianite, witherite, cerussite and aragonite, but never calcite). Blount (1974) discussed the synthesis of celestite, anglesite and strontianite.

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[1] Joint Committee on Powder Diffraction Standards – Powder diffraction file search manual, Inorganic Compounts, Alphabetical Listing.

Strontium is widely dispersed in the lithosphere (see Table 9) but rarely forms independent minerals in igneous rocks. It does however, substitute for calcium in lattices of early-formed plagioclase. In potash feldspar, it replaces potassium more readily than does barium because of the greater similarity in ionic radii of strontium and potassium. Strontium also occurs in micas, pyroxenes and amphiboles, although in micas, which have fewer calcium positions it is less abundant than barium. The calcium positions in apatite may also be partly filled by strontium. The bulk of strontium in magmas enters the early-formed, high-temperature feldspars of both igneous intrusive and extrusive rocks; thus magmas as a rule do not become enriched in strontium until late in the differentiation process. Zircon, perovskite, catapleiite, eudialyte and calcium garnets may contain up to six per cent strontium (Rankama and Sahama, 1950). Strontium does not replace the rare earth elements because bivalent elements cannot replace trivalent elements without making the crystal structure unstable, but it does accompany these elements in either calcium or lead positions.

Strontium occurs principally as celestite, rarely as strontianite, in a variety of chemical sediments. These include limestone, dolomite, aragonitic oolites, and sabkha and playa-type evaporites. Carbonate rocks may receive strontium from accumulations of organisms, aragonitic oolites that contain trace amounts of the element, and solutions from which the rocks were precipitated. Subsequent diagenesis converts the strontium-bearing aragonite into calcite or dolomite, neither of which can tolerate the element in their lattices. The strontium from this source is dissolved in pore solutions and in groundwater. These solutions transport the element considerable distances to new deposition sites to form veins and replacement bodies. This process may explain the occurrence of nodular masses, coatings on solution cavity walls, geode fillings and replacement bodies in, for instance, Paleozoic limestones of southern Ontario, eastern Nova Scotia and western Newfoundland.

Sabkha and playa-type evaporites are locally characterized by the mineral celestite. The mineral may be precipitated directly from seawater and playa brines at the close of the halite evaporite stage or during the magnesium-potassium sulphate evaporite stage (Gale, 1951; Wood and Shaw, 1976). Analytical results suggest the celestite-depositing brines were enriched in Sr relative to Ca and that concentrations exceeded those of normal pore solutions or brines derived from seawater. The lack of excess sulphate anions would suppress deposition of anhydrite in favour of celestite. This preference could also be due to diagenetic reaction between the residual brine and pre-existing sediments. Strontium is also deposited indirectly as a trace element in the lattice of gypsum crystals during the sulphate evaporite stage. The element is freed by subsequent diagenesis as the primary gypsum is replaced by anhydrite. The element is accumulated in pore water for subsequent deposition elsewhere. Celestite occurs in modern sabkhas in Iran (Evans and Shearman, 1964) and in continental playas having no input from the ocean (Gale, 1951).

The behaviour of strontium in metamorphic rocks has been studied to only a limited degree. Sedimentary rocks that normally host strontianite or celestite apparently lose their high strontium content when they are metamorphosed. The metamorphic conditions of high temperature and pressure and low free-oxygen affect these minerals. The carbonate radical is altered to carbon dioxide, the sulphate anion is reduced to sulphide and the strontium ion enters the formation solutions. The solutions then move in accordance with physical and chemical gradients to favourable sites where celestite can precipitate as veins or replacement deposits.

Weathering Processes

Strontium enters groundwater solutions as a result of biochemical and chemical weathering processes which free the element from independent strontium minerals and strontium-bearing silicates in soil and bedrock. Both bacteria and plants accumulate the element and promote its solution by bicarbonate-rich groundwaters, which in most cases transport the strontium to its main destination in the oceans.

Biogeochemistry

Fossil Fuels

Fossil fuels have a limited role in the geochemistry of strontium (Veizer, 1972). Some coal seams are enriched in strontium as a result of primary biological concentration and, possibly, subsequent diagenetic processes.

Terrestrial Animals

Terrestrial animals accumulate some strontium in their tissues. The bones of some animals contain strontium in trace amount that does not appear to substitute for calcium in the bone structure and does not have a recognizable physiological function.

Marine Animals

Marine animals play a greater role in the accumulation of strontium. Skeletons of certain planktonic radiolaria (e.g. **Acantharia**, Veizer, 1972) and foraminifera are enriched in the element relative to the surrounding water. The dead animals transport strontium downwards to a repository in the pelagic sediments. Although this mechanism does not appear to concentrate strontium in carbonaceous or siliceous argillite formations with the same efficiency as the parallel barium-accumulating process it may offer an explanation for the celestite nodules reported in limestones. Freshwater snails and clams (e.g. **Cardium edule**), may have similar concentrations of strontium and the Sr/Ca ratio may be a useful criterion to distinguish between freshwater and marine species.

Bacteria

Certain bacteria convert both strontium and calcium carbonates into soluble bicarbonates. Elsewhere anaerobic bacteria may also facilitate the crystallization of celestite in sediments.

Mineralogy

Thirty-eight strontium-bearing minerals were listed by Fischer (1972b), Vlasov (1966) and Fleischer (1975) (see this report, Table 11). Few strontium minerals have been studied in detail and some minerals, not normally strontium-bearing, can contain significant amounts of the element without being recognized as strontium minerals. Celestite, strontianite, lamprophyllite, veatchite and goyazite are the most completely described. Celestite and strontianite are the commercial sources of the element. The properties of these and other less common strontium minerals are summarized in Table 11.

The strontium minerals are mainly oxygensalts, oxide (1), carbonates (4), sulphates (2), vanadates (2), borates (6) and silicates (3). There is only one halide and there are no naturally-occurring sulphides. Strontium minerals exhibit specific gravities between 3.0 and 4.0 and hardness does not exceed 5.0. They are generally colourless, pale yellow or pale blue and in thin sections are transparent, colourless to weakly coloured and have, with rare exceptions, characteristically low birefringence.

Table 10. Well described barium-rich minerals including, major source of the element, potential byproduct source or prospecting guide

Name	Chemical Composition	Ba Content %	Symmetry	Specific Gravity	Hardness	Colour
CARBONATE, SULPHATE						
Alstonite	$Ca.Ba(CO_3)_2$	48.54-52.3	orthorhombic	3.707 ±0.004	4.0-4.5	Colourless, white, grey, pink, red
Barytocalcite	$BaCa(CO_3)_2$	51.76	monoclinic	3.65, 3.66 3.71	4	colourless, white, grey, green, yellow
Witherite	$BaCO_3$	77.70	orthorhombic	4.291 ±0.002	3-3.5	colourless, white, grey, pale yellow, brown, green
Barite	$BaSO_4$	60.30-65.70	orthorhombic	4.50	3-3.5	colourless, white, grey, yellow, brown, red, rarely green or blue
NITRATE						
Nitrobarite	$Ba(NO_3)_2$		isometric			colourless
PHOSPHATE, ARSENATE VANADATE						
Dussertite	$Ba,Fe_3(AsO_4)_2(OH)_5H_2O$	20.93, 22.37	hexagonal	3.75		
Ferrazite	$(Pb,Ba)_3(PO_4)_2.8H_2O$	8.87		3.0-3.3	3.5	green, pistachio green, yellow-white
Gorceixite	$Ba,Al_3(PO_4)_2(OH)_5H_2O$	11.88-29.98	hexagonal	3.036-3.185	6	brown, mottled brown
Uranocircite	$Ba(UO_2)_2(PO_4)_2.8H_2O$	15.16, 14.57	tetragonal	3.53	2-2.5	pale canary yellow
SILICATES						
Barylite	$BaBe_2,Si_2O_7$		orthorhombic	4.0	6-7	colourless
Hyalotekite	$(Pb,Ca,Ba)_4B(Si_6O_{17})$ (F,OH)	3.81	orthorhombic?	3.81	5-5.5	white, grey
Benitoite	$BaTiSi_3O_9$		hexagonal	4.4	6	greenish brown
Taramellite	$Ba_4(Fe^{+2}, Mg)Fe_2^{+3}$ $TiSi_8O_{24}(OH)_4$		orthorhombic	3.9	5.5	reddish brown
Gillespite	$BaFe(Si_4O_{10})$		tetragonal or hexagonal	3.33	4	red
Celsian	$Ba(Al_2Si_2O_8)$		monocline	3.37	6-6.5	colorless
Harmotome	$(K_2Ba)Al_2Si_5O_{14}.5H_2O$		monoclinic	2.44 -2.50	4.5	white, grey, yellow, red, brown
Edingtonite	$BaAl_2Si_3O_{10}.3H_2O$?		orthorhombic	2.694	4-4.5	white, grey, pink
OXIDES						
Hollandite	$Ba_2Mn_8O_{16}$	17.59, 20.56	tetragonal or pseudotetragonal	4.95	6	Silver-grey, grey-black, black
Psilomelane	$(Ba,H_2O)Mn_5O_{10}$	14.40-17.48	orthorhombic	4.71 ±0.01	5-6	iron black, steel grey
Todorokite	$(Mn,Mg,Ca,Ba,Na,K)_2$ $Mn_5O_{12}.3H_2O$	2.05	monoclinic	3.67	soft	brown

Source: Fleischer, 1975; Palache et al., 1957; Fischer, 1972a.

Habit	Mineral Association	Occurrence
psuedohexagonal,dipyramidal, repeated twins, rarely untwinned	calcite, barite, witherite, galena	low temperature hydrothermal deposits, Alston, Hexham, New Brancepeth, U.K.
short to long prisms, equant	barite, calcite, fluorite,	veins, Alston, U.K.; Mies, Badenweiler, Freiburg, Germany; Langban, Sweden; cements shale limestone breccia, Mile 498, Alaska Hwy (94-15),B.C.; vein Kingdon Mine (3194), Ont.
pseudohexagonal, dipyramidal, short prisms, tabular, globular, tuberous, botryoidal, columnar,fibrous	baritegalena veins; coal measures; calcite-alstonite barytocalcite-silver	Austria, Germany; France, England; Russia; Japan; U.S.A.; Canada; cements shale limestone breccia, Mile 498, Alaska Hwy. (94-15), B.C.; Porcupine mine (52-25), Ont.
dipyramidal, well crystallized, tabular, concretionary, rosettes, massive, granular, cryptocrystalline	fluorite, calcite, siderite, dolomite, quartz, galena, manganite, stibnite, hematite	widespread: Asia, Europe, North America. veins in limestone, Brisco (82-42), Parson (82-44), Silver Giant (82-43), B.C.; in granite, Cryderman (Ravena) (42-03), Ont.; replacement, Walton (21-13), N.S.; stratiform, Tea (105-18) and Tom (105-22), Y.T.
octahedral crystals	nitrate minerals	nitrate deposits, Chile
minute crystals, rosettes, crusts	quartz, arsenosiderite, carminite	Constantine, Algeria; Durango, Mexico
discoidal pebbles	diamonds	Minas Gerais, Brazil
grains, pebbles	diamonds	Minas Gerais,Brazil; Dompim, Bonsa River, Ghana, Sierra Leone; Zimbabwe; Guyana
crystals resemble autunite	quartz, fluorite, autunite, secondary uranium minerals	Bergen, Schneeberg, Saxony,; Wolsendorf, Bavaria; Srdnia Gûra, Hungary; Rosmaneira, Spain
platy crystals		Varmland, Sweden; Franklin, N.J., U.S.A.; with alkali syenite, Seal Lake, Labrador
massive, coarse crystals		Varmland, Sweden; Franklin, N.J., U.S.A.
rhomboidal prisms		Langesundfiord,Norway
fibrous		limestone, Piedmont, Italy
		Dry delta, Alaska Range, Alaska., U.S.A.; contact skarn, Gunn Claims (105-16), Y.T.
cleavable, massive, twinned by Carlsbad, Manebach, and Baveno laws		Nordmark District, Varmland, Sweden; Toce valley, Italy Piedmont, Italy
uniformly cruciform, penetration twins, double twins resemble square prism with diagonal pyramid	chabazite, agate, stilbite	eruptive rocks; gneiss; veins in Bavaria, Rhineland, Harz Mtn., Germany; Kongsberg, Norway; Argyll, Scotland; Lake Superior region, U.S.A. Craigmont Mine B.C.
	harmotome	Dumbarton, Scotland; Ostergotland, Sweden
short prismatic,massive, fibrous crystals	quartz, manganese minerals	Jhabua; Sitapur, Banswara, India; Madagascar
massive, botryoidal, reniform, mammilary, crusts, stalactitic, earthy, pulveruent	chalcophanite, braunite, altered Mn-carbonates, secondary surface goethite, limonite, hausmannite	Schneeberg, Eibenstock, Thuringia, Germany; Romania; France; Ottrez, Belgium; Orkney Islands, Scotland; India; United States. Residual and replacement, Markhamville (21-22), N.B. B.E.A.R. Property, Labine Bay, N.W.T.; Walton Mine (21-13), N.S.
spongy, banded, reniform, aggregates of minute lathlike crystals	inesite, alteration, product; rhodochrosite, opal	Todoroki mine, Hokkaido, Japan

Table 11. Well described strontium-rich minerals including, major source of the element, potential byproduct source or prospecting guide

Name	Chemical Composition	Sr Content %	Symmetry	Specific Gravity	Hardness	Colour
OXIDES						
Pandaite	$(Ba,Sr)_2(Nb,Ta,Ti)_2O_7.xH_2O$	6.40	cubic	4.01	4.5-5.0	yellowish gray, olive green
HALIDES						
Jarlite	$Na,F.3SrF_2.3AlF_3$	35.60	monoclinic	3.78-3.93	4-4.5	gray
CARBONATES						
Strontianite	$SrCO_3$	70.19	orthorhombic	3.76 ±0.02	3.5	colourless, gray, yellow-green, red, brown
Burbankite	$Na_2(Na,Ce,Ba,Sr,Ca)_6(CO_3)_5$	12.46-19.72	hexagonal	3.50		gray-yellow
Carbocernaite	$(Ce,Na,Sr,Ca)CO_3$	12.43	orthorhombic	3.53	3	colourless, yellow, pink
Ancylite	$SrCe(CO_3)_2(OH).H_2O$	17.10-21.03	orthorhombic	3.95	4-4.5	pale yellow, orange, brown, gray
SULPHATES						
Celestite	$SrSO_4$	56.42	orthorhombic	3.9-4	3.9-4	bluish white, blue, gray blue, red, pink, yellow
Kalistrontite	$K_2Sr(SO_4)_2$	24.35	trigonal	3.20, 3.32	2	colourless
PHOSPHATES						
Belovite	$CeNaSr_3(PO_4)_3(OH)$	33.60-39.31	hexagonal	4.19	5	honey yellow
Strontium apatite	$(Sr,Ca)_5(PO_4)_3(F,OH)$	46.06	hexagonal	3.84	5	pale green, yellow-green
Fermorite	$(Ca,Sr)_5((P,As)O_4)(F,OH)$	9.93	hexagonal	3.518	5	pale pink, white
Bøggildite	$Na_2Sr_2Al_2(PO_4)F_9$	31.89	monoclinic	3.66	4-5	flesh pink
Palermoite	$(Li,Na)_4Sr,Al_9(PO_4)_8$	9.20	orthorhombic	3.22	5.5	colourless, white
Svanbergite	$Sr,Al_3(SO_4)(PO_4)(OH)_6$	12.84-17.99	trigonal	3.22, 3.24	5	colourless, yellow, red brown
Sokolovite	$(Sr,Ca,Mg)_5Al_{16}(PO_4)_8(SO_4)_2$	11.45-11.80		2.94	2.5	white
Tikhvinite	$(Sr,Ca,Mg)_3Al_{12}(PO_4)_4(SO_4)_2(OH)_{26}$	11.52-24.43		3.12-3.32	2.5-4.5	white
Goyazite	$SrAl_3(PO_4)_2(OH)_5.H_2O$	17.33-19.8	trigonal	3.26, 3.29	4.5-5	colourless, pink, honey-yellow
Lusungite	$(Sr,Pb)Fe_3(PO_4)_2(OH)_5.H_2O$	20.24	hexagonal			
VANADATES						
Delrioite	$CaSrV_2O_6(OH)_2.2H_2O$	26.26	monoclinic	3.1 ±0.1	2	yellow green, dark green
Santafeite	$Na_2O.2MnO_2.6(Mn,Ca,Sr)O_3(V,As)_2O_5.8H_2O$	6.0	orthorhombic	3.379		black
BORATES						
Veatchite	$SrB_6O_{10}.2H_2O$	29.5 -30.72	monoclinic	2.58-2.69	2	colourless, white
Tunellite	$Sr(B_6O_{10}).4H_2O$	27.72	monoclinic	2.40	2.5	
Strontioginorite	$(Sr,Ca)_2(B_{14}O_{23}).8H_2O$	10-20	monoclinic		2-3	colourless
Kurgantaite	$(Sr,Ca)_2(B_5O_8)(OH)_2Cl$	37.48				
Strontiohilgardite	$(Ca,Sr)_2(B_5O_8)(OH)_2Cl$	25.39	triclinic		5-7	pale yellow
Strontioborite	$4(Ca,Sr)O.2MgO.12B_2O_3.9H_2O$	21.66	monoclinic?			Colourless
SILICATES						
Brewsterite	$(Sr,Ba,Ca)(AlSi_3O_8)_2.5H_2O$	8.99	monoclinic	2.45	5-	white, yellow, gray
Lamprophyllite	$Na_{4,4}Sr_2Fe_2Ti_4Si_6O_{25}F_2$	14.12-16.73	orthorhombic	3.44-3.53	2-3	yellow-brown, dark brown
Nordite	$CeNa_3SrMn_2Si_6O_{18}$	7.40	orthorhombic	3.43-3.49	5	light, dark-brown

Source: Fischer, 1972; Vlasov, 1964; Fleischer, 1975.

Habit	Mineral Association	Occurrence
cubic crystals	variety of pyrochlore biotite, orthoclase, fluorite apalite, zircon, chlorite, columbite, sphene	Mbesta, Tanganyika - hydrothermal product, niobium-tantalum oxide
minute crystals, tabular (100), spherulitic, porcelaneous	cryolite, chiolite, weberite, fluorite, topaz, thomsenolite pyrite, chalcopyrite	Ivigtut, Greenland - pegmatite, druses in replaced barytocelesite
short to long acicular prisms, spear shaped, massive, columnar, earthy	barite, celestite, calcite, sulphides	Munster, Germany - limestone, clay, marl; Strontian, Scotland; fluorite ores Kuli Kolon, Kopet Dagh, kimberlite pipes, Yakutia, U.S.S.R.; Horsefly Mine (93-01), B.C.;* Nepean Twp. (31-92) and Frazer-Duntile Quarry (31-02), Ont.; Isle Ste. Helene (31-99), Quebec.
prismatic crystals to 3 cm	barite, calcite, ancylite	Bearpaw Mountains, Montana; - hydrothermal veins; alkali granosyenite; ankeritic carbonatite, U.S.S.R.; Mt. St. Hilaire, (31-106), Que.
pinacoids and prisms	dolomite, calcite, chlorite, ancylite, sphalerite	carbonatite, Vuoriyari Massif, U.S.S.R.; Madagascar strontium carbonate
pseudo octahedral crystals		druses in pegmatite, nepheline syenite, Julianehab, Greenland. Mt. St. Hilaire (31-106), and Oka Mine (31-97), Que.
thin to thick tabular crystals (001)	low temperature veins with galena, sphalerite, barite, fluorite	veins in dolerite, Tunisia; barite-witherite veins, Kopet-Dagh, U.S.S.R.; low temperature fluorite veins, Kentucky; evaporites, California; Iran Rexspar Property (82-50), B.C.; Wilder Property (31-89), Frontenac Lead Mine (31-09), Frazer-Duntile Quarry (31-02), Ont.; Cheverie Cliffs (2109) and Kaiser Celestite Mine (11-27), N.S.; Gillams Brook (12-01), Nfld.
prismatic, elongated, crystal intergrowths	halite, anhydrite	Persian, saline anhydrites
prismatic to 2 cm	nordite, steenstrupine, chkalovite	Lovazero alkali massif, Kola Peninsula, U.S.S.R.; cerium strontium hydroxy phosphate
subhedral spherical crystals, oval to to circular cross-section	aergirine-akermanite, albite	alkaline pegmatite, Inaglinskii massif, U.S.S.R.
massive, granular aggregates	brookite, hollandite, pyrolusite	manganese veins Sitapur, India
columnar crystals	fluorite, quartz, pyrite, sphalerite, zircon	low temperature hydrothermal replacements barytocelestite, Ivigtut, Greenland
prismatic	siderite, apatite, goyazite, braunite, brazilianite, crandallite	Palermo, New Hampshire, pegmatites
rhombohedral, pseudo-cubic, granular	quartz, kyanite	Horrsjôberg, Sweden - crystals in quartzite; Westona Iron mine, Skane, Sweden - supergene
crusts	bauxite	Sokolovskoe, U.S.S.R.
small aggregates	bauxite	Tichvin, U.S.S.R.
small pseudo-cubic crystals, tabular, rhomb faces striated	diamonds, pyrite, bertrandite apatite, herderite, palemroite	Minas Gerais, Brazil - diamond sands; Valais, Switzerland - with pyrite in dolomite; Simplon, Switzerland - in anhydrite;
powdery coating on limonite	limonite	Kivu, Zaire - Kobokobo phosphate-rich pegmatite
aggregates, fibrous crystals, powdery rosettes, radial fibrous acicular aggregates		coating on sandstone, Salt Wash Seriet, Joe Dunley Mine, Montrose, Co., Colorado
rosettes, radial fibrous acicular aggregates	carnotite, tyuyamunite uranophane, uraninite, fluorite barite, pyrite, etc.	Grant, New Mexico, in Morrison formation limestone, workings uranium-vanadium mine - supergene product
platy, slender prisms, fibrous, cross fiber veins	colemanite	on colemanite crystals in limestone, cross-fiber veins Lang, California
nodules	inderite, kurnakovite, ulexite	Kramer, California, borate deposit - supergene origin
	halite	supergene salt beds, Gôttingen, Germany
nodules	sylvite, carnallite, halite, anhydrite	supergene, Inderskoe Highland, U.S.S.R.
small crystals	halite, anhydrite, sylvite, celestite, magnesite, hematite	supergene origin - Gôttingen, Germany
mica-like sheets, misroscopic	halite, boracite, halurgite	Kungurian salt beds - primary sedimentary origin
short prismatic crystals, tabular	galena	hydrothermal mineral - St. Turpet, Federal Republic of Germany
crystals, crystal aggregates	nepheline, aegirine	alkali intrusions, Kola Peninsula, U.S.S.R., pegmatites - South Africa and Norway
crystalline lamellar, radial-fibrous aggregates	sodalite, ussingite, murmanite, chkalovite, belovite, steenstrupine	rare. agpaitic sodalite syenites; ussingite pegmatites; cerium silicate.

Fluorine

Geochemistry

Fluorine is the 14th most abundant element in the lithosphere (Koritnig, 1972; Table 9, this report). It is a pale yellow, highly toxic, pungent gas. The boiling point is 188.14°C (1 atm.), the density 1.696 g/l (1 atm.) and the specific gravity at the boiling point is 1.108 g/l (see Table 8). Fluorine is a member of the Halogen Group (chlorine, fluorine, bromine and iodine). Fluorine, chemically the most electronegative and reactive of all elements, reacts with practically all organic and inorganic substances. Consequently, a great number of valuable fluorine compounds have been synthesized, forming the base for a large chemical industry. The fluorine anion has several coordination numbers, depending upon the structure of the compound. Six isotopes of fluorine have been identified but only one, ^{19}F, is reported in nature.

Fluorine substitutes in a few structural sites in natural materials in response to the fluorine content of the environment, the lattice positions occupied by OH^- and O^{2-}, ions of similar ionic radii and valences, polarizabilities and electronegativities. The fluorine anion commonly substitutes isomorphously for OH^-, less commonly for O^{2-}, Cl^-, $CO_3{}^{2-}$ and rarely in the complex anions $(BF_4)^-$, $(AlF_6)^{3-}$ and $(SiF_6)^{2-}$. For example F^- and OH^- substitute for one another to produce the mineral series fluorapatite-hydroxyapatite. To a lesser degree F^- substitutes for either Cl^- or $CO_3{}^{2-}$ in the same mineral series. Substitution for O^{2-} positions is more characteristic of the occurrence of fluorine in micas and amphiboles. The complex anion $(AlF_6)^{3-}$ occurs in the mineral cryolite and the complex anion $(SiF_6)^{2-}$ is restricted to volcanic emanations.

Fluorine tends to accumulate in the igneous plutonic environment (see Table 9). It has a strong affinity for SiO_2 in basaltic, granitic and alkalic magmas and increases in abundance with increases in silica and alkali contents. It is most abundant in the residual differentiates because the common, early-formed silicates are unable to take the element into their lattices. The major fluorine-bearing minerals in granites include biotite, muscovite, hornblende, apatite, topaz, fluorite and tourmaline. Fluorine depresses the melting temperature of the magma, and facilitates the formation of pegmatites. Unlike Sr and Ba, F is enriched in the pegmatitic stage of crystallization differentiation to the extent that independent mineral species may form economic deposits. The fluorine-bearing minerals in this case include micas, apatite, fluorite, topaz, tourmaline and pyrochlore (the latter in alkalic pegmatites only). Fluorite is more abundant in complex pegmatites than in the mineralogically simple pegmatites.

Ultramafic and alkaline ultramafic rocks have a minimal fluorine content. Fresh ultramafic rocks generally have low F contents but the serpentinization process results in fluorine enrichment. Fluorine substitutes for OH^- and micaceous ultramafic rocks are especially enriched in the element. The main fluorine host minerals in ultramafic rocks include phlogopite, biotite, serpentine, augite and hornblende.

Carbonatites in general exhibit a large range of fluorine concentration because the principal host minerals (fluorite, apatite and pyrochlore) show different concentration levels in different phases of the carbonatite. Fluorine is also associated with rare earth elements (REE), niobium and tantalum in these rocks.

In the volcanic environment fluorine is partitioned between the gaseous and melt phases, particularly on or near the surface. The effusive melts degas readily, and hydrated minerals are less commonly formed than gaseous fluorine. The crystallization of minerals with OH^- groups reduces the number of positions into which F^- can be bound, and half the fluorine present is lost as HF or H_2SiF_6 through fumaroles directly to the atmosphere. In general volcanic rocks have a lower fluorine content than their intrusive equivalents although they show a parallel increase of F^- with increasing silica and alkali content.

Fluorine is enriched in some clastic sedimentary rocks. The element occurs in resistate minerals such as apatite and mica, or adsorbed on clay minerals in shales, siltstones and mudstones. The amount of fluorine present is generally proportional to the clay content and to the amount of phosphatic minerals present. Fluorite also cements some sandstones, as in West Cumberland, England and in Colorado, U.S.A. (Notholt and Highley, 1971; Grogan et al., 1974). The latter case is characterized by the association of fluorite with uranium minerals. The fluorite in these environments may have been deposited by either groundwater or hydrothermal solutions.

Some chemical sediments including anhydrite, gypsum, salt, limestone and dolomite have anomalous fluorine contents. Trace amounts of the element are precipitated from the brines in the carbonate and sulphate phases of deposition and before the halite phase. The average fluorine content is the same for both limestone and dolomite although the range of values is less for the latter rock type.

The fluorine minerals and dispersed fluorine in regionally metamorphosed rocks, greisens and skarns owe their fluorine content to some combination of primary sedimentation and subsequent metasomatic introduction. Regional metamorphism of sedimentary rocks results in the mobilization of pore solutions and weakly held constituents such as CO_2, S, SO_3, Cl, K_2O, Na_2O, and F. These are freed from clay, mica and other resistate minerals by rising temperature and pressure in the presence of water. They travel along chemical-potential gradients and are eventually precipitated at sites where the pressures and temperatures are lower, the wall rock is more reactive or fewer volatile constituents are present. They may even escape to the atmosphere. The original sedimentary rocks lose half their fluorine content, and other volatile constituents as well when they become schists, gneisses or marbles.

In the second case (metasomatism) the primary fluorine content is augmented by fluorine emitted by intrusive felsic stocks. This additional fluorine is produced by crystallization differentiation of the intruding magma and introduced into the country rocks to form a contact aureole. The volatiles under high temperatures and pressures partially replace country rock constituents in lime-rich sedimentary rocks to form marbles and skarns. In silicate-rich sedimentary rocks and granites they formed hornfels and greisen, respectively. The latter may be characteristic of cupola development at the top of batholiths, where the host granitic rocks have themselves been attacked and replaced, greisenized or kaolinized. In the latter case, fluorine may substitute in the kaolinite lattice or crystallize as fluorite. Fluorine and lithium concentrations are commonly characteristic of greisenized granites which may contain a variety of potentially economic minerals including fluorite, topaz, tourmaline, lepidolite, muscovite and tin and tungsten minerals.

Weathering Processes

Fluorine is freed from source rocks and soils by a combination of chemical and mechanical processes. Acidic groundwaters dissolve the element from fluorapatite, fluorite, fluorine-bearing mica and amphibole. Both fluorapatite and fluorite are sparingly soluble and, along with other resistates such as topaz, tourmaline and micas, are generally mechanically transported by water into sedimentary basins. Chemically, fluorine anions are adsorbed on particulate matter or colloidal acceptors, complexed with hydrogen, iron, aluminum, boron and silica or occur as the anion in groundwater. This is the most important transportation medium; less important are wind and rain. Fluorine concentration and mode of occurrence are influenced by temperature, pH, total ionic strength, presence of complexing or precipitating colloids, solubility of source minerals, nature of the source geological environment and the time of exposure to the groundwater. Calcium-rich solutions will depress the solubility of fluorine whereas sodium-rich solutions will serve to increase the solubility of the element.

Biogeochemistry

Fossil Fuels

Fossil fuel residues, such as coal ash, contain as much as 100 ppm fluorine. The fluorine accumulation is attributed to a combination of the life processes of the original plants and subsequent diagenetic or hydrothermal enrichment.

Terrestrial Plants

Terrestrial plants such as tea (**Theaca** sp.), elderberry (**Sambucus** sp.) and Camellia (**Ebander elegans**) have been reported to carry from 100 ppm to 8200 ppm; 1400 and 6400 ppm fluorine (dry weight) respectively (Matuura et al., 1954). Nevertheless, terrestrial plants on the average contain about 10 ppm of the element. More fluorine accumulates in the roots and leaves than in the wood, bark, fruit or seeds. The roots absorb the element directly from the solutions in soils that are enriched in fluorine by the decomposition of colloids and minerals such as apatite and micas. The mechanism by which fluorine is taken from the soil is poorly understood but lime-rich soils inhibit fluorine uptake (MacIntire et al., 1955) whereas acidic and alkaline soils encourage greater uptake. Fluorine complexing with aluminum, iron and boron may favour greater uptake. Volcanic emissions and, more significantly, industrial emissions cause anomalous enrichment of fluorine in the leaves of garden vegetables. Until recently fluorine in plant tissues was believed to be restricted to fluorapatite but it is now known that it also occurs as toxic organo-fluorites such as fluoracetate, fluoroleic and fluor-palmitic acids (Hall and Cain, 1972). Only one plant, the epiphyte Spanish moss (**Tillandsia usneoides**) is known to absorb fluorine from the atmosphere. High atmospheric fluorine contents are toxic to plants. No plants are known to thrive on fluorine-rich soils (Boyle, 1976). Regardless of its form fluorine apparently performs no essential function in land-plant nutrition.

Terrestrial animals

Terrestrial animals accumulate fluorine mainly in skeletal tissues in fluorapatite whereas soft tissues rarely contain more than 5 ppm (dry weight). The element is accumulated in bones of beef cattle especially when they are pastured downwind from industrial complexes that emit fluorine to the atmosphere. Animals that eat vegetation and drink water with excessive fluorine may suffer from a condition known as fluorosis. The hydroxyapatite in bones and tendons is replaced by fluorapatite causing increased brittleness, calcification of the tendons, and disintegration of teeth. On the other hand, trace amounts of fluorine are necessary to produce strong bones and reduce the incidence of dental caries.

Marine animals

Marine animals take up fluorine in the phosphate of skeletal tissues to a greater degree than do the terrestrial species. Fluorapatite is produced in warm oceans by a combination of chemical and biochemical processes on shelf areas receiving little or no sediment from the adjacent landmass. Such ocean areas are characterized by phosphate-rich, upwelling, cold water and abundant benthonic and planktonic life forms. Phosphate pellets recovered from the continental shelf off the west coast of Baja California contain phosphatic brachiopod valves (**Disciniscus cumingii**, BRODERIP), fluorapatite-encrusted siliceous diatom tests and partly-replaced carbonate tests of **Uvigerina Sp.** and other less abundant benthonic and planktonic foraminifera (D'Anglejan, 1967). It is uncertain whether or not the fluorapatite is wholly biochemical in genesis. Fossil fish teeth from the Carboniferous rocks at Joggins, Nova Scotia provide an example of fluorine enrichment in fossils. Certain marine shells may contain sufficient fluorine for the mineral fluorite to form.

Mineralogy

Fluorine is reported in 150 rock-forming minerals, few of which are economically important or well known (Allmann, 1972; Boyle, 1976; Fleischer, 1975) (see Table 12 this report). In addition, there is a long list of artificial compounds. Fluorine minerals and compounds are much more abundant than those of Ba and Sr and the study of the artificial compounds of fluorine is of considerable economic importance. The most common fluorine-bearing minerals are fluorite, topaz, fluorapatite and cryolite, all of which have either been mined or are potential sources of the element. The fluorine content of fluorapatite is less than 4 per cent but the known deposits of the mineral are so large as to constitute the world's main commercial source of the element (Montgomery, 1974). The better known fluorine-bearing minerals are summarized in Table 12.

Fluorine occurs in several classes of minerals: simple halides (3); halides with fluoro-anions (14); carbonates (1); phosphates (2); arsenates (3); silicates (6) and oxides (1). Of the fluorine-bearing halides only fluorite is an important rock-forming and economic mineral. The remainder occur only as accessory minerals. Fluorite, villiaumite and sellaite are the simple fluorides; the remainder such as hydrated alumino-fluorides are variable in composition.

The fluorine-bearing minerals vary in fluorine content from 1.41 (svabite) to 61.44 per cent (cryolithionite). Hardness ranges from about 2 to 7.5 and specific gravity ranges from about 2.5 to 5.2. Fluorine minerals range from colourless or white to shades of a variety of colours, including red, blue and green. Fluorite is particularly notable for a variety of colours localized in irregular areas or geometric zones within individual crystals. Such variations are attributed to defects in the crystal lattice and the colours are affected by exposure to sunlight, gamma- and X-radiation.

GEOLOGY OF BARIUM, STRONTIUM AND FLUORINE

General Remarks

Barium, strontium and fluorine minerals, either singly or in combination, occur in a variety of geological settings. Because of their tendency to occur in association with each other, as well as in association with the common metallic ore minerals (galena, sphalerite, chalcopyrite, etc.) it is difficult to establish an unambiguous deposit-type classification (see Tables 30, 31). Consequently, a primary classification into two main classes – syngenetic and epigenetic – is followed here and no attempt is made to correlate this with any of the detailed classification schemes developed for the metallic sulphide deposits in which one or more of the three elements are frequently found.

Table 12. Well described fluorine-rich minerals including those that are major sources of the element, potential sources of byproduct fluorine production or prospecting guides

Name	Chemical Composition	F content %	Symmetry	Specific Gravity	Hardness	Colour
HALIDES						
Villiaumite	NaF	44.2, 45.28	Isometric	2.79	2-2.5	carmine, colourless
Fluorite	CaF_2	48.9	Isometric	3.180 ±0.001	4	colourless, many colours, colour effected by light etc.
Yttrofluorite	CaF_2YF_3		Isometric	+3.180	+4	yellow, brown, violet blue
Yttrocerite	$(Ca,Ce)F_{2-2.33}$	25.45	Isometric			
Sellaite	MgF_2		Tetragonal	3.15	5	colourless, white
Cryolite	Na_3AlF_6	54.4	Monoclinic	2.95-3.0		colourless, snow-white, reddish, brownish, brick-red, black
Nocerite	$Ca_3Mg_3F_8O_2$	37.55-40.30	Hexagonal	2.96		white, brown, green
Hieratite	K_2SiF_6	51.9-51.76	Isometric	2.665	2.5	colourless, white, gray
Malladrite	Na_2SiF_6		Hexagonal	2.714		pale rose, white
Pachnolite	$NaCaAlF_6.H_2O$	51.33-51.54	Monoclinic	2.983	3	colourless, white
Thomsenolite	$NaCaAlF_6.H_2O$	50.61-51.34	Monoclinic	2.981	2	colourless, white, brownish
Gearksutite	$CaAl(OH)F_4.H_2O$	35.25-42.68	Monoclinic	2.768	2	white
Chiolite	$Na_5Al_3F_{14}$	51.30-57.81	Tetragonal	2.998	3.5-4	snow white, colourless
Ralstonite	$Na(Mg,Al_5)_6F_{12}(OH)_6.3H_2O$		Isometric	2.56-2.62	4.5	colourless, white, milky, yellow
Creedite	$Ca_3Al_2F_4(OH,F)_6(SO_4).2H_2O$	25.85-30.30	Monoclinic	2.713	4	colourless, white, purple
Ferruccite	$NaBF_4$		Orthorhombic	2.496	3	colourless, white
Cryolithionite	$Na_3Li_3Al_2F_{12}$	60.79-61.33	Isometric	2.770	2.5-3	colourless, white
CARBONATES						
Bastnaesite	$(Ce,La)(CO_3)F$	6.24-9.94	Hexagonal	4.9 -5.2	4-4.5	
PHOSPHATE, ARSENATE VANADATE						
Amblygonite	$(Li,Na)Al(PO_4)(F,OH)$	9.00-12.83	Triclinic	3.11	5.5-6	white, yellow, beige, salmon pink, green, blue, gray, colourless
Tilasite	$CaMg(AsO_4)F$	7.18-8.55	Monoclinic	3.77 ±0.02	5	gray, violet-gray, olive to apple-green
Durangite	$NaAl(AsO_4)F$	7.67-9.14	Monoclinic	3.94-4.07	5	orange, red, green
Fluorapatite	$Ca_5(PO_4)F$	.80-4.10	Hexagonal	3.1-3.2	5	sea green, bluish green, violet, blue, colourless, white, brown, red
Svabite	$Ca_5(AsO_4)_3F$	1.41-2.28	Hexagonal	3.5-3.8	4-5	colourless, yellow, white, gray, green
SILICATES						
Topaz	$(Na,Ca)\ (Mg^{2+},Fe^{3+},Al,Li)_3Al_6(BO_3)_3Si_6O_{18}(OH)_2$	20.7	Orthorhombic	3.4-3.6	8	yellow, white, gray, green, blue, red
Tourmaline	$MgAl_3(B,OH)_2Si_4O_{19}$?	minor amount	Rhombohedral	2.98-3.20	7-7.5	black, brown, blue, green, red, white, colourless
Lepidolite	$(OH,F)_2KLiAl_2Si_3O_{10}$	minor amount	Monoclinic	2.8-3.3	2.8-3.3	rose, violet, lilac, yellow, gray, white
Biotite	$H_2K(Mg,Fe)_3Al(SiO_4)_3$	minor amount	Monoclinic	2.5-3.0	2.7-3.1	green, black, red, brown, rarely white white
Hornblende	$RSiO_3$ normal metasilicate, Ca, Mg, with Fe, Mn alkali metals Na, K and Ti, F and H_2O	minor amount	Monoclinic	2.9-3.4	5-6	black, white, green, brown, rarely yellow, pink, red.
Vesuvianite	$Ca_6((Al(OH,F))Al_2(SiO_4)_5$		minor amount			
OXIDES						
Pyrochlore	$(Na,Ca)_2(Nb,Ti)_2(O,F)_7$.?	minor amount	Isometric	4.2-4.36	5-5.5	brown, red, black

Habit	Mineral Association	Occurrence
massive, granular		Miarolytic cavities in nepheline syenite, French Guinea; Kola Peninsula, U.S.S.R.; United States; salt pans, Rift Valley, Africa
simple cubes, octahedrons	numerous species	mainly veins with or without metallic sulphides; hot springs; pegmatites; Freiberg, Altenburg etc. Germany, U.S.A. etc. Rock Candy Mine (82-09), B.C.; Perry Mine (31-17), Silver Mtn (52-13), Ont.; Director Mine (1-27), Nfld.; Rainville (Dugas) Mine (21-49), Mt St. Hilaire (31-106), Qué.; Fiddler Yukon (10-55), Y.T.
massive granular		Hundholmen, Norway; Khibina tundra, U.S.S.R.
granular aggregates	xenotime, monazite	Falun, Sweden
stout prismatic, acicular, fibrous aggregates	native sulphur, fluorite, quartz, celestite	Moutiers, France; Bleicherode, Germany; Carrara, Italy; Nertchinsk, U.S.S.R.
cubes, grouped parallel position, often twinned, massive		Ivigtut, Greenland; Pikes Peak, U.S.A., Miass, Ilmen Mountains, U.S.S.R.; Mt. St. Hilaire (31-106), Que.
acicular, fibrous aggregates	fluorite, biotite, hornblende, hematite	metamorphosed limestone blocks in bedded tuff, Nocera, Campania, Italy.
cubo-octahedral, octahedral, stalactites spongy to dense aggregates	sassolite, mirabilite, glauberite, realgar, alum	Lipari Islands, Vesuvius, Italy
prismatic crystals	sal ammoniac, avogadrite, hieralite, ferruccite	crusts on lava, Vesuvius, Italy
prismatic crystals, massive, stalactitic	cryolite, thomsenolite, elpasolite	Ivigtut, Greenland; Pikes Peak, Colorado
prismatic, cubic, opaline crusts, stalactites	cryolite, pachnolite, ralstonite, fluorite, cryolithionite	Ivigtut, Greenland; Miass, U.S.S.R.; Pikes Peak, Colorado
massive, nodules, earthy, chalk-like minute needles	cryolite, thomsenolite	Ivigtut, Greenland; Miass, U.S.S.R.; Pikes Peak, Colorado Gringin, W. Australia.
crystals rare, massive, granular	cryolite, topaz, phenacite, fluorite, cryolithionite,	Miass, U.S.S.R.; Ivigtut, Greenland.
octahedral, small or cubo-octahedral	thomsenolite thomsenolite, cryolite, pachnolite	Ivigtut, Greenland; Pikes Peak, Colorado; Tanokamiyama, Japan
short prismatic acicular radiating aggregates, drusy	barite, kaolinite, gearksutite	Wagon Wheel Gap, Colorado; Granite, Nevada, Colquiri, Bolivia.
tabular crystals	hieralite, avogadrite, sassolite, mallaroite	Vesuvius, Italy.
dodecahedral, cubic	cryolite	Ivigtut, Greenland; Miask, U.S.S.R.
tabular, anhedral masses	allanite, cerite, fluocerite, cerite, britholite	Vastmanland, Finbo, Sweden; Kyshtym, U.S.S.R.; Madagascar; Zaire; South Africa; Jamestown, Pikes Peak, Colorado New Mexico; Mountain Pass, Colorado, Rexspar (85-50), B.C.; Haliburton Co., Ont.; Mt St. Hilaire (31-106), Que.
small short prismatic crystals, cleavable masses, columnar, compact	spodumene, lithiophilite, apatite, lepidolite, petalite, etc.	widespread in Li and P type granite pegmatites; West Hawk and Bernic Lake, Man.; Yellowknife, N.W.T.; Cosgrave Lake, Ont.; New Ross, N.S.
flattened crystals, sub-parallel groups, massive	berzeliite, barite, hausmannite	Langban, Sweden; Kajlidongri, India.
prismatic crystals	cassiterite, hematite, topaz	Durango, Mexico; New Ross, N.S. in pegmatites
short to long prisms, massive, coarse, granular, bedded		widespread in felsic and alkaline intrusive rocks and pegmatites.
short prisms, massive	schefferite, garnet, brandtite, sarkinite, hausmannite, hematite, mica, franklinite	Pajsberg, Jakobsberg, Langban, Sweden; Franklin Furnace, New Jersey
prismatic crystals, columnar, granular	rock forming silicate minerals; pegmatitic tin minerals	Nerchinsk, Transbaikalia, U.S.S.R.; Europe; Durango and San Luis Potosi, Mexico; Maine, Colorado, California,; Seagull Cr. (10-53), Y.T.; Shatford Lake and Winnipeg River, Man.; Burnt Hill Creek (21-42), N.B.
prismatic slender acicular, prism faces strongly striated, massive, compact, columnar	rock forming silicates quartz, albite, cassiterite, muscovite	widespread in granite, gneiss, fumerolic deposits, contact metamorphosed limestone. Nerchinsk, Transbaikalia, U.S.S.R.; Czechoslovakia; Switzerland; Norway; United Kingdom; United States; Canada; Bernic Lake and Winnipeg River, Man.; Madoc and Murphy-Hickey Mine (31-52), Ont.,; Leduc and Villeneuve mines (31-130), Québec
short prisms, massive, scaly, granular	rock forming silicate minerals granite, pegmatite with muscovite	Ural Mountains, U.S.S.R.; Neustadt, Czechoslovakia; Maine, California, West Kootenay, B.C.; Bernic Lake, Man., comté de Papineau, Lacorne and Mt St. Hilaire (31-106), Qué.; New Ross, N.S.
short prisms, dissemianted scales, massive aggregates	essential rock forming mineral	widespread
commonly prismatic, columnar, fibrous granular, massive	essential rock-forming mineral	widespread
	grossularite, phlogopite, diopside, wollastonite	Mount Vesuvius, Italy; product of contact metamorphism not in intrusive rocks; Canada Tungsten mine (105-11), Y.T.; Texada Island, Kamloops, Ashcroft, B.C.; Frontenac and Hastings Counties, Ont., Black Lake, comté de Papineau and Mt. St. Hilaire, Québec.
Octahedrons, grains	nepheline	Fredriksvårn, Larvik, Norway; Miass, U.S.S.R.; Bugaboo Creek (85-40), Blue River, Lonnie Property, B.C.; McDonald Mine (31-87), Woodcox Mine (31-88), Nova Beaucage (31-133) and Cardiff Uranium Mine (31-75), Ont.; Oka Mine (31-97), Mt St. Hilaire (31-106), Québec

Following customary terminology, syngenetic deposits are those in which the economic mineral formed contemporaneously with the host rock. They may be characterized by relatively uniform distribution of the ore minerals (e.g., barite in volcanogenic massive sulphide bodies; fluorapatite in gabbro and strontianite in syenite). Consequently, the syngenetic classification scheme adopted for these elements is closely related to the lithology of the host rock and the characteristics of other enclosing materials (see Tables 15, 23, and 27). Barite, for example, occurs as an economic constituent of some volcanogenic massive sulphide deposits of the Kuroko type, illustrated by the Buchans Mine in Newfoundland. Other syngenetic deposits have a sedimentary rock association, a stratiform or layered morphology and generally large lateral extent relative to thickness.

Epigenetic deposits are those in which the economic constituents were introduced following consolidation of the host rock(s) (see Tables 19, 25, 28). They include: 1. replacement deposits; 2. skarn deposits and 3. structurally controlled vein deposits. Replacement deposits are illustrated by the Mineral King Mine (82-34), British Columbia and the Walton Mine (21-13), Nova Scotia. The skarn deposits are illustrated by the Canada Tungsten Mine (105-12), in western District of Mackenzie, NWT, near the Yukon-NWT boundary. The vein deposits are illustrated by the Creswel (52-25, -26, -29) and Dorion (52-84), mines, Thunder Bay, Ontario.

In the discussions that follow, individual classification tables together with Canadian or foreign deposit-type examples are presented in the sections treating barium, strontium and fluorine separately. Syngenetic and epigenetic deposits are tabulated separately for each element but have been combined in the summary at the close of the chapter to illustrate the interrelationships. The geological characteristics, classification and "type" deposits are discussed in this chapter using data compiled in the data bank (see below) and the appropriate literature.

The data bank (file) constructed during the course of this study contains descriptions (records) for 733 Canadian occurrences of Ba, Sr or F or some combination of the three elements (see Appendix A). Although a large number of these records lack detailed data, 226 producers, past producers and developed prospects were identified. Generally, these have sufficient geological data to permit description and classification. Quantitative statistics were compiled for all records (733) in which barium, strontium or fluorine was one of the four most abundant elements. The statistical elements include the principal element present, the ore minerals, the gangue minerals, the wall rock type and the geological age of the wall rock. The appropriate statistics are presented in the following sections in the introductory comments about each of the three elements.

Barium

The following data on chemical composition, ore mineralogy, gangue mineralogy, wall rock type and wall rock age have been compiled for barium deposits and occurrences from the 733 records (property descriptions) in the data file. A total of 446 records contain Ba and 240 of these have the element in the first position. Barium also occurs as a minor or trace constituent with fluorine (52 records), lead (47), silver (29), zinc (23), copper (16), (see Table 13) and less commonly with other elements.

A search of the same population (446) for the most abundant ore mineral showed barite in the first position in 240 records and as a trace to minor constituent with major fluorite (55 records), galena (52), sphalerite (22), silver (17) and chalcopyrite (11), and less commonly with other minerals (see Table 13). The gangue minerals were compiled for 317 of the barite records and these were dominated by quartz (125), calcite (121) and pyrite (12) and less commonly by other minerals.

The 240 deposits and occurrences having barium as the most common element have a great variety of wall rocks, although limestone (70 records), dolomite (9) and marble (36) are the most common (see Table 13). The wall rocks are mainly Phanerozoic in age (248) with a peak abundance in the Early to Middle Paleozoic.

Syngenetic Deposits

The barium deposits classified here as syngenetic are contemporaneous products of the processes – igneous extrusion and sedimentation – which formed the rocks in which they are contained. With one exception, barium rarely forms independent minerals in igneous intrusive rocks. A few carbonatite intrusions such as the Firesand River (41-12) carbonatite contain independent barium minerals (Heinrich and Vian, 1967). Subsequent to their formation, the syngenitic deposits were generally not subjected to supergene or hydrothermal alteration. The syngenetic deposits are discussed under two main groups (Table 14); those formed in igneous extrusive rocks and those formed in sedimentary rocks. Deposits of these two groups have not yet produced barite in Canada although the volcanogenic massive sulphide ore of the Buchans (12-10) deposit and one or more of the bedded baritites[1] of the northern Cordillera could become economic sources of barite in the future.

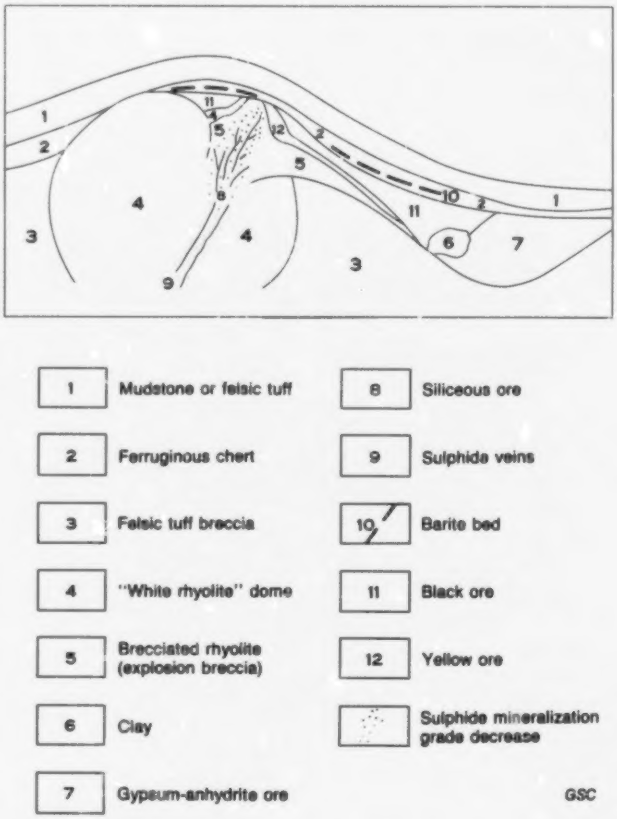

Figure 1. *Schematic section of a typical Kuroko orebody.*

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[1] Baritite is a sedimentary rock composed chiefly of the mineral barite. It is used as a rock name in the same sense as chromitite, pyroxenite, amphibolite and similar terms for essentially monomineralic rocks.

Deposits in Igneous Extrusive Rocks

Intermediate Flows and Pyroclastics

Barite occurs in economic amounts associated with these rocks as exhalative products of submarine and sublacustrine volcanic activity, the best documented examples being the massive sulphide bodies of the Kuroko district, Japan. The latter commonly consist of lenses and beds of massive barite, as well as sulphide ores. In addition the sulphide ores usually contain barite gangue.

Kuroko-type deposits, Japan. These (Lambert and Sato, 1974; Aoki et al., 1970) are lenticular in plan, often flat lying when structurally undisturbed, and are conformable with their wall rocks (see Fig. 1). They are related to submarine volcanism and appear to have formed on lava domes on or near the base of volcanic cones. They have a spatial relationship to dacitic or rhyolitic lava flows, pyroclastic and derived volcanogenic sedimentary rocks. They are characterized by a stratigraphic zonation of the mineral assemblages which, from top to bottom, is typically in the order: ferruginous-manganiferous-siliceous mudstone – massive barite – massive sphalerite-galena-barite – pyrite and chalcopyrite and siliceous pyrite-chalcopyrite. The sulphide minerals are also disseminated mainly in the footwall volcanic rocks, in vein stockworks or in compact homogeneous aggregates. The contact between the massive sulphides and the overlying barite is usually sharp with the sulphide zone thinning towards, and usually terminating abruptly at, its margins. Less commonly it may grade into small discontinuous lenses and patches of massive sulphides.

Table 13. Characteristics of Canadian Ba-bearing deposits

Most abundant element	
Ba	240*
F	52
Pb	47
Ag	29
Zn	23
Cu	16
Au, Mn, Si, Fe	5-10
Nb, U, Hg, Mo, Se, S, Ca	1-4
Total	446**
Dominent ore mineral	
barite	242
fluorite	55
galena	52
sphalerite	22
silver	17
chalcopyrite	11
celestite	9
gold	5-8
pyrochlore, tetrahedrite, rhodochrosite, cinnabar, ilmenite, argentite, molybdenite, arsenopyrite, hematite, chalcocite, pyrolusite, limonite, pyrite, magnetite, manganite	1 ea
Dominant gangue minerals	
quartz	125
calcite	121
pyrite	12
hematite, carbonates, limonite	4-9
apatite, siderite, fluorite, specularite, amethyst, jasper, sericite, chalcopyrite, chert, epidote, dolomite, serpentine, galena, mica, ankerite, graphite, marcasite, flint	1-4

Geological age of the host-rocks	
Phanerozoic	248
Cretaceous	9
Jurassic	30
Triassic	10
Mississippian	30
Pennsylvanian	8
Carboniferous	34
Devonian	48
Ordovician	32
Cambrian	17
Proterozoic	165
Archean	19
Host rocks	
Igneous intrusive rocks	
granite	33
diabase	24
Igneous extrusive rocks	
andesite	12
basalt	10
rhyolite	7
other volcanic rocks	6
tuff	13
Metamorphic rocks	
quartzite	9
slate	26
phyllite	3
gneiss	4
sericite schist	9
Clastic sediments	
sandstone	20
argillite	16
arkose	6
iron formation	4
Chemical sediments	
limestone	20
dolomite	9
marble	36

*240 records of the 446 that have mainly Ba reported

**Ba is one of the first four elements reported.

The main structural controls are volcanic cones and lava domes extruded in a submarine environment. The deposits occur on the flanks of such structures, conform to the enclosing volcanic or volcanogenic rocks, and are not spatially related to known faults. Locally diabase dykes cross cut the ore. The overlying flows and sedimentary beds are moulded to the tops of orebodies which lie conformably on the underlying beds. Both tops and bottoms of the orebodies have sharp contacts with enclosing rocks except for the contact between the black baritiferous sulphide ore and the underlying massive chalcopyrite-pyrite ore. This contact may be gradational.

The wall rocks in the type area, the central and northern parts of the Japanese island of Honshu, are dacitic or rhyolitic lavas, pyroclastic rocks, volcanogenic sedimentary rocks and some mudstones. The latter contain a Miocene fauna. Locally, post-ore mafic dykes cut across the orebodies.

The Kuroko-type volcanogenic massive sulphide ore deposits may have beds of nearly pure massive barite or gypsum adjacent to the massive sulphide bodies as well as disseminated barite in the sulphide ore. Consequently such deposits can carry economic amounts of barite, which can be recovered directly in some cases or as a byproduct of the base metal milling process.

Canadian Examples of Kuroko-type Deposits. A number of Canadian deposits exhibit features similar to those of Kuroko type (Table 14). The best example is probably the Buchans deposit (12-10) of central Newfoundland, which is described below in some detail as a type deposit. The Lynx deposit (92-04) of Western Mines Ltd. on Vancouver Island (Jeffrey, 1964) and the Jane orebody (92-06) of the Britannia Mine on Howe Sound, British Columbia (Bratt et al., 1972; Sutherland Brown, 1969) also represent volcanogenic massive sulphide deposits that contain significant barite.

Buchans Mine. The Buchans mine is Canada's best example of massive, polymetallic sulphide orebodies of the Kuroko-type

(Fig. 2). The Buchans mine is at the western edge of the Central Mobile Belt of Newfoundland (Williams et al., 1972; Relly, 1960; Thurlow et al., 1975). The immediate area is underlain by the rocks of the Buchan Group, consisting of latest Ordovician to mid-Silurian calc-alkaline, bimodal basalt-rhyolite and andesite-dacite volcanic rocks, and red fluviatile-continental clastics combined with greywacke and volcano-clastic rocks (Hutchinson, 1981). The sedimentary and volcanic rocks have been intruded by sills and dykes of rhyolite, trachyte and diabase and several large Devonian granite intrusions to the north and west of the mine.

Table 14. Examples of volcanogenic massive sulphide (Kuroko-type) and stratiform baritite deposits

Classification	Name	Province or Country	Wall Rock Age
Volcanogenic massive sulphide (Kuroko-type) deposits	Lynx (Western Mines) (92-04)	B.C.	Lower Permian
	Twin-J (92-01)	B.C.	Permo-Carboniferous
	Seneca (92-02)	B.C.	Upper Jurassic
	Britannia (Jane) (92-06)	B.C.	Upper Jurassic -Lower Cretaceous
	Buchans (12-10)	Nfld.	Ordovician
Stratiform baritites	Wise (105-28)	N.W.T.	Upper Devonian - Mississippian(?)
	Tom (105-24)	Y.T.	Upper Devonian
	Tea (105-19)	Y.T.	Upper Devonian
	Cirque (94-26)	B.C.	Upper Devonian
	Driftpile Creek (94-24)	B.C.	Upper Devonian
	Stevens County, Washington State	U.S.A.	Ordovician-Carboniferous
	Battle Mtn., Nevada	U.S.A.	Devonian
	Meggen	Federal Republic of Germany	Middle Devonian

The mine is underlain by the rocks of the Buchans Group which have been divided into upper and lower subgroups (Thurlow and Swanson, 1981). The massive sulphide deposits are concentrated near the top of the Lower Subgroup. The lowest unit, the footwall basalt, consists mainly of basaltic pillow lava, pillow breccia, minor pyroclastics, massive flows and interbedded chert, more than 2000 m thick. Mineralization is limited to a small pyrite-chalcopyrite-sphalerite body. The footwall arkose is mainly lithic arkose, with lesser arkosic conglomerate, siliceous greywacke, minor siltstone, mudstone and chert. The thickness is estimated at about 2500 m. Mineralization is limited to a small bedded pyrite-galena-sphalerite occurrence. The intermediate footwall consists of mainly complexly interbedded andaltered mafic to felsic flows pyroclastics, and breccias about 250 m thick. An ore-grade pyritic stockwork and subeonomic disseminated sulphides occur in the unit. The Lucky Strike ore horizon is mainly dacitic tuff, massive rhyolitie, pyritic siltstone and wacke about 200 m thick. The large, highgrade orebodies, Lucky Strike, Rothermere and MacLean occur in this unit. The Lake Seven basalt consists of barren flows and minor pyroclastics 350 m thick. The Prominent Quartz sequence consists mainly of dacitic pyroclastics and minor related sedimentary rocks and interbedded basalt 2000 m thick. The unit contains some areas of disseminated sulphides. The Ski Hill sequence, 1000 m thick, is mainly andesitic pyroclastics and minor basalt flows 1000 m thick. Local fragments of black ore have been identified. The Oriental Intermediate unit consists of pumiceous felsic pyroclastics, local intermediate and mafic flows 300 m thick. Sulphides are limited to minor ore-grade stockworks and larger subeconomic disseminated epigenetic galena-sphalerite-chalcopyrite. The Oriental Ore Horizon, 400 m thick, consists of dacite tuff, rhyolite breccia domes, pyritic siltstone and wacke and granite conglomerate. This unit contained the high grade sulphide bodies called: Oriental No. 1, and Oriental No. 2.

The Upper Buchans Subgroup consists of mafic to felsic pyroclastics and breccia with lesser flows and a basal member known as the Upper Arkose. The latter "arkose" member is a reworked conglomerate. The whole unit is approximately 200 m thick. No economic occurrences of sulphides have been found in the unit.

The geological environment, in the mine area, began with calc-alkaline volcanic centres in a shallow marine setting. The volcanoes produced flows, pyroclastics and polymict breccias that were subsequently intruded by diabase dykes and sills and to the north and west, by large granite batholiths. The modern structure of the area is characterized by broad, open folds that are warped from the regional northeasterly trend of the Central Mobile Belt to an east-west trend in a crustal segment about 6.5 km in length that contains the Buchans mine. Strata dip generally 30° to 75° north but in the mine area attitudes are locally locally erratic. Major transgressive shears have not been recognized but a set of east-trending conjugate faults are present. Intense deformation is rare and the rocks are regionally metamorphosed to greenschist facies.

The ore zones are divided into three classes: in situ, transported and stringer zone. The first two classes were the main source of ore in the Buchans Mine. The Lucky Strike stockwork and overlying in situ ore can be directly related to a volcanic vent. Other ore bodies, such as the Clementine consist of transported ore and wall rock fragments deposited in paleotopographic submarine depressions. The Clementine ore body has not been related to a vent probably because of faulting (Hutchinson, 1981). The in situ ore bodies are characterized by textures and structures attributable to submarine deposition. The main orebodies (Lucky Strike, Rothermere, MacLean, Oriental and Old Buchans) are regular in shape, grade, and attitude, and have been the main source of sulphide ore. They range from lensoid to tabular and in maximum dimension form 480 m (Oriental No. 2) to 375 m (main Lucky Strike). Three types of ore are recognized breccia ore, baritic ore and normal ore. The breccia ore, which lies conformably within the enclosed wall rock, contains a variety of wall rock and barite fragments. The baritic ore occurs in conformable bands containing minor sulphides and in some cases capping massive sulphide bodies. The normal ore is massive sulphide type with minor quartz and barite gange.

Ten orebodies have been delineated in the Buchans Mine area distributed over a strike length of 6.5 km. The overall grade of the ore mined is 26% barite, 14.62% zinc, 7.60% lead, 1.34% copper, 116 g/t silver, 1.4 g/t gold. Between 1928 and 1978, 15 499 120 tonnes of ore were milled to produce 5 577 995 tonnes of concentrate.

Sphalerite, occurring in both fine- and coarse-grained, brown crystals, galena (blankets, segregations and inclusions in sphalerite) and chalcopyrite are the chief ore minerals, with sphalerite dominant. Tetrahedrite, native silver and argentite are minor to rare. Barite, quartz and ubiquitous pyrite are the principal gangue minerals. Barite occurs in subhedral grains and massive aggregates of fine grained anhedral grains widely distributed through the massive sulphide ores and, as noted elsewhere, it locally forms beds and lenses that cap some sulphide orebodies. Such barite concentrations are generally associated with calcite and fluorite, both of which occur in late faults cutting the ore zones.

Barite is widespread in the Buchans orebodies, occurring as a major constituent in the sulphide (sphalerite, galena, chalcopyrite, pyrite) ores. Tailings from the mill operation which have been ponded since 1968, contain in excess of 500 000 tonnes or 30% $BaSO_4$. The tailings require minor processing to make a marketable barite concentrate. With the phasing out of sulphide concentrate production in 1978, the mill was modified to process and recover a barite concentrate. Barite production on a seasonable basis commenced in 1980. It is estimated that 30 000 tonnes of barite concentrate can be produced per year.

Table 15. Classification of syngenetic barium deposits[1]

Classes	Examples
Intermediate flows and pyroclastics	Buchans (12-10), Nfld.; Lynx Mine (Western Mines Ltd) (92-04), Britannia Mine (Jane) (92-06), B.C.; Kuroko, Japan.
Clastic sediments	
Eluvial deposits	Washington County, Missouri; Brunswick No. 6 sulphide deposit (21-46), N.B.
Alluvial deposits	Grand Forks (115-08), Y.T.; Alaska Highway Mile 397-110 Cr(94-10), Mile 472 (94-15), B.C.; South Newbridge (21-35), N.B.
Sands and gravels	Dierks, Ark.; Guthrie, Okla.
Marine shales	Tom property (105-24) and Moose Group (105-21), Y.T., Wise Claims (105-28), District of Mackenzie; Stevens Co., Wash.; and Battle Mtn., Nev.; Meggen Mine, Federal Republic of Germany.
Chemical sediments	
Carbonates	Sulphur Creek (94-13); and Alaska Hwy Mile 397-110 Creek (94-09),B.C.[2]
Bioclastic and biochemical sediments	
Hydrocarbons	Coal Measures, Derbyshire, U.K.
Surface waters, groundwaters and brines	Traces in river waters and groundwater[3]; hot brines; lake waters in the African rift system[4]

[1] See page 53

[2] Veins and cavity fillings in bedrock

[3] Livingstone, 1963; Lalonde, 1973

[4] United Nations Development Program, 1973

The Buchans ore bodies and the typical Kuroko deposits of Japan are similar in many respects. Both are stratiform, polymetallic deposit with breccia horizons in felsic volcanic sequences. The ore and gangue mineralogies are strikingly similar but Buchans ore contains neither anhydrite nor gypsum. According to Thurlow and Swanson (1981, p. 138) the Buchans ore is similar to the Kuroko ores: "Imbrication, bedding and sag structures, graded sulphide breccias, scouring at the base of the deposits and ore balls surrounded by clay are features of the transported Kuroko ores which have also been identified in both Kuroko and Buchans deposits."

The orebodies have sharp contacts but internal banding and colloform structures are less well developed in the Buchans ore. Mechanically transported ores occur in both countries but the distance of transport in the Buchans mine is much greater (Thurlow and Swanson, 1981, p. 139). Yellow ore is much less abundant at Buchans whereas black ore is higher grade and more abundant. White rhyolite bodies are present in the Buchans orebodies but according to Thurlow and Swanson (1981, p. 139) "white rhyolite bodies do not seem to display the intimate spatial and genetic relationship to mineralization which is so characteristic of the Kuroko deposits."

The orebodies resulted from the complex interaction between polymetallic volcanic exhalations, the wall rocks and seawater in a submarine volcanic environment. It has been suggested that the ore solutions were either primary products of the same shallow magma chamber that produced the volcanic rocks or were produced by convecting seawater reacting with the volcanic rocks. The role of seawater in the formation of the ores is not fully understood but it may have been the source of much of the sulphur.

Deposits in Sediments and Sedimentary Rocks

Clastic Sediments

Eluvial Deposits. Eluvial deposits are the products of residual weathering that have not undergone physical transportation from the source area other than minor downslope creep. Solution and redeposition of the ore mineral is also minimal. The residual deposits of Washington County, Missouri, have been productive for over 100 years from a number of sites in the district (Brobst, 1958; Wharton, 1972; Brobst and Wagner, 1967; Mather, 1946). Here, barite occurs in Paleozoic formations ranging from Cambrian to Pennsylvanian in age but is most important in the dolomites of the Upper Cambrian Potosi and Eminence formations. Barite, chalcedony, pyrite and drusy quartz occupy fractures and voids in the algal reef portions of the Potosi Formation and the lower part of the Eminence Formation. The residuum overlying the latter two formations is the main source of the barite. The depth of barite-bearing residuum ranges from several centimetres to 15 m and the barite content varies horizontally and vertically, a feature that is attributed to the original distribution of barite in the rocks prior to weathering. Locally, the distribution is modified by hillside creep that results in movement of barite concentrations from their immediate source area. The individual barite fragments retain the colour, textures and structures observed in the unweathered underlying carbonate rocks. The barite occurs as fragments ranging from small chips to large lumps weighing several hundred kg

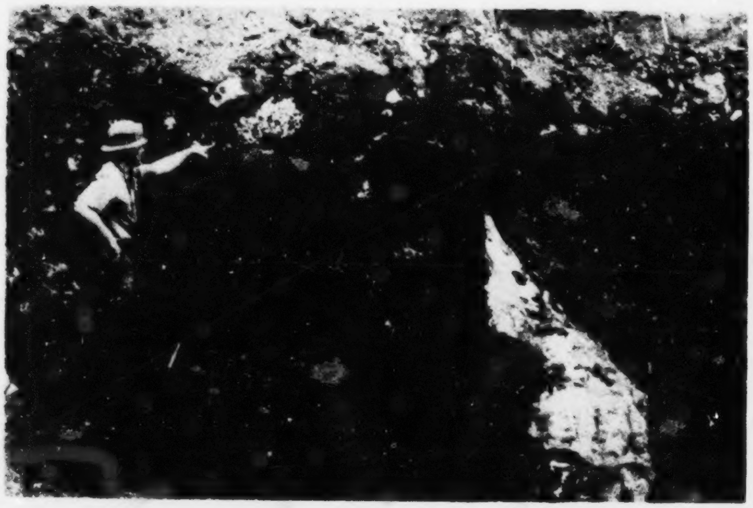


Figure 3A. *Open-pit face showing residual barite in red soil and a limestone pinnacle relict of bedrock limestone. Wolf Mine, Washington, County, Missouri. GSC 202886-R*

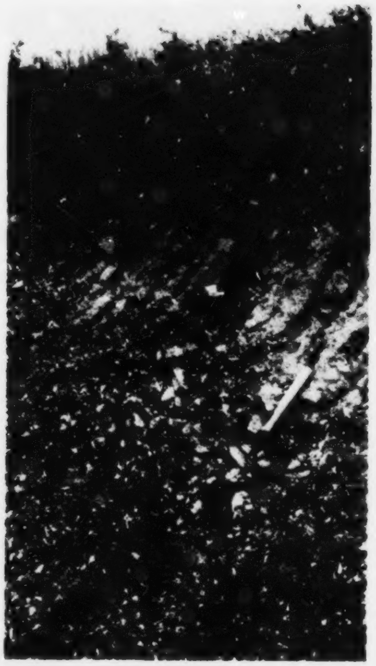


Figure 3B. *Open-pit face "gravel-spar" in red soil beneath loess and turf. Dillinger Tract, Washington County, Missouri. GSC 202031-A*

(Fig. 3A, 3B) and is associated with chert, drusy quartz and limonite fragments. Local pinnacles of unweathered bedrock project upwards into the residuum and complicate mining operations.

In the Sweetwater District, Tennessee, barite is also produced from residual soils, in this case developed above the Ordovician Knox Group, and especially on carbonate rocks of the Kingsport Formation (Brobst, 1958; Maher, 1970). Where exposed beneath the ore deposits and bedrock contains veins and breccia zones cemented by barite, fluorite and pyrite and a few local concentrations of sphalerite and galena. The thickness of the ore-bearing clays averages 10.5 m, but locally ranges from a few metres to more than 30 m. Average barite content is 200 tonnes per (1900 tonnes per hectare metre) and the ores characteristically occur irregularly distributed in pockets separated by barren areas.

Canadian examples of residual barite are rare. Barite was reported in the residual gossan that originally overlay the No. 6 orebody (21-46) of the Brunswick base metal mine in the Bathurst District, New Brunswick (Boyle and Davies, 1964). Although not of economic importance the occurrence demonstrates that local preservation of residual material can occur even in the glacially-scoured Appalachian Orogen.

Alluvial Deposits. Alluvial barite has been found in both modern and fossil placer deposits. The mineral constituents were mechanically weathered from primary source rocks and were then transported significant distances from the point of origin. The detrital barite grains show little evidence of solution and recrystallization.

Alluvial deposits, as far as known, have not been a commercial source of barite and such occurrences are, at present, of mineralogical rather than economic interest.

Barite was reported in alluvial gravels of placer gold creeks of the Klondike area, Yukon Territory by Gleeson (1970) who found five per cent barite in the − 60 + 100 mesh heavy liquid concentrates of samples collected at several points along Bonanza and Eldorado creeks. Barite was derived from gold-quartz-barite veins in the underlying Klondike schist series. Alluvial barite and fluorite were observed by the writer in the beds of 110 Creek (94-10), and creeks at Mile 472 (94-15) on the Alaska Highway, which drain west into Muncho Lake, British Columbia. At both locations, barite occurs as cobbles and boulders of bedded or vein material derived from the Devonian Dunedin, Stone and Wokkpash formations that outcrop at higher elevations in the same valleys (Fig. 4A, 4B). Barite is present in lag deposits at the top of the Devonian Wokkpash Formation (Taylor and Stott, 1973). These occurrences indicate a greater than average content of the mineral in the sedimentary rocks of the area.

Barite fragments, pebbles and cobbles identified in the till at South Newbridge (21-35), New Brunswick were traced to a local source, a vein in the underlying grey Ordovician shales (Hamilton, 1968).

Sands and Gravels. Unconsolidated sands and gravels contain barite cement and barite roses (see below) but the mineral rarely occurs in economic amounts. Occurrences of this type are not known in Canada, but a few United States examples are described here since they represent environments that may yet be discovered in Canada.

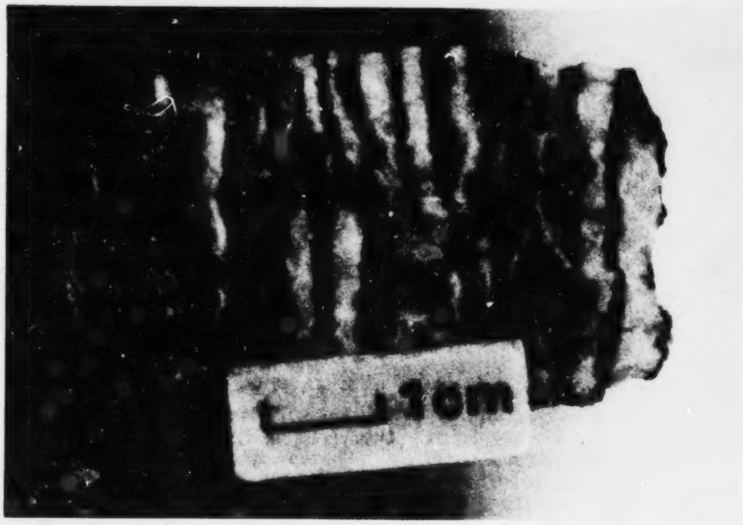


Figure 4A

Thinly bedded dolomitic limestone replaced by white barite and purple fluorite. Collected in 110 Creek Canyon. Mile 397, Alaska Highway. (094-009) GSC 203007-N

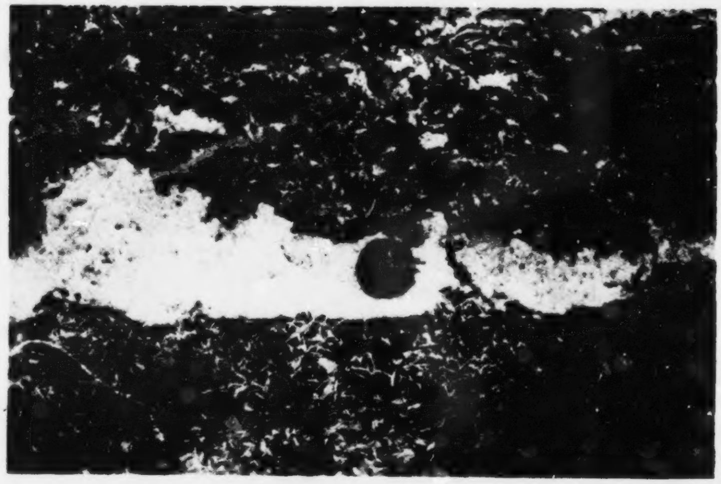


Figure 4B

Conformable calcite-barite vein and barite crystals replacing the dolomite walls of a solution cavity. Collected in 110 Creek. Canyon. Mile 397, Alaska Highway. (094-009) GSC 202886-B

The best example of barite of this type occurs in the basal Pike gravel of the Lower Cretaceous Trinity Formation, in the Dierks District, Arkansas (Scull, 1958). The Trinity Formation lies horizontally above an angular unconformity that truncates steeply dipping Carboniferous sediments. The former unconformably underlies the Upper Cretaceous Woodbine and Tokio formations in the Dierks District. The barite fills voids in weakly cemented gravels and sands in which clay and iron oxides occur sparsely as cementing agents. Barite is limited to uncemented areas and consequently its distribution is variable both horizontally and vertically, resulting in lenticular bodies of barite-rich sediments. Barite crystals 7.5 to 10 cm long fill the voids, and contain abundant more or less isolated detrital quartz grains. Some barite crystals have grown in radial aggregates and these are freed by a combination of weathering and erosion as "barite roses".

The Pike gravel and the overlying Trinity sandstones represent a strand line at the margin of the Lower Cretaceous sea. The barium was extracted from bedrock in the source terrain and transported to the strand line in chloride form or adsorbed on clay particles. Where these solutions encountered sea-water charged with sulphate radicals, barite was precipitated in the pores of the unconsolidated sediments.

Marine Shales. Barite interlaminated with black shale, chert, and siltstone, and rarely associated with conglomerates, is a widespread deposit-type that has good economic potential. Typically the barite beds or laminae occur in stratigrapic sections consisting of baritite, siltstone, argillite, chert and minor carbonate beds. These are commonly blackened by amorphous carbon and foetid as the result of trapped gaseous H_2S. The author recognizes bedded baritites of two types: (1) white or buff baritiferous siltstone, siliceous argillite or laminated chert (i.e., high-silica, low-carbon type); and (2) black shale or bedded chert with grey to black barite laminae or conformable nodule bands (i.e. moderate silica-high carbon type).

The mineralogy of these two types of barite deposits noted above is similar and both contain up to 95% barite associated with fine grained quartz, chert and clay minerals.

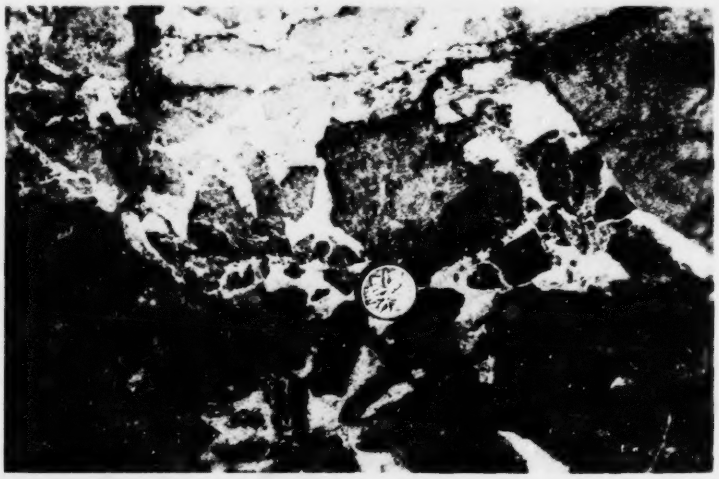
Sulphides, with a few exceptions (e.g. Tom deposits 105-24 in Yukon Territory and the Meggen deposit in the Federal Republic of Germany) are rarely present in significant amounts and generally limited to pyrite or marcasite, galena and sphalerite. Minor to trace constituents include quartz, chert, calcite, witherite, barytocalcite, dolomite, siderite and secondary iron oxides (Cronan, 1974; K.M. Dawson, 1977; Lydon et al., 1979).

The author considers that both the high silica and high carbon types may have formed by one of two alternative processes – hydrothermal replacement of fine grained clastic and carbonate sedimentary rocks or to normal sedimentary and diagenetic processes. Hydrothermal replacement is related to nearby centres of igneous activity and to identifiable channels to egress through which the ore solutions travelled. Replacement deposits (e.g. Walton mine 21-13) are characterized by irregular form of the orebodies, crosscutting relationships with the wall rock, association with mineralized structures, and the common occurrence of one or more of Cu, Pb, Zn, Hg, and Mo in the ore. Replacement origin is considered unlikely for the bedded baritites discussed here even if it is assumed replacement could reproduce the delicate laminations and sedimentary structures. Crosscutting relationships and other disruptions of the sedimentary sequences characteristic of replacement processes have not been reported.

The sedimentary origin of bedded baritites is supported by the widespread occurrence of baritite in stratigraphic sections dominated by chert and shale – Wise 105-28, Tom west 105-24, Dawson, 1977; siltstone – Stevens County, Washington State, (Mills et al., 1971) and rarely conglomerate – Tom east 105-24, Dawson, 1977 and Jason south 105-22, (Lydon et al., 1979). Deposition took place in a basinal, often reducing, environment into which a limited amount of clay-size material was introduced accompanied by abundant organic debris. The clastic material is well sorted, very fine grained quartz and clay and the organic material is mainly in carbonaceous or cherty silica except in the Macmillan Pass area where turbiditic and conglomeratic sediments occur with the baritite. The clastic material were either derived from a mature source terrain no longer supplying coarser clastic materials or from an immature terrain supplying coarser materials that were sorted and left the fine material for transportation seaward and deposition at abyssal depths. K.M. Dawson, who has worked recently in the area states: "Cherty Devonian-Mississippian sediments at Macmillan Pass originate largely from uplifted older cherts (Road River) and siliceous clastics (Grit). However, cherts and cherty siltstones closely associated with Ba-Pb-Zn beds probably are chemically precipitated from hydrothermal solutions. Hence cherty sediments are both (1) clastic and (2) chemical in origin." (personnal communication, 1982).

Figure 5A

Solution collapse breccia in limestone cemented by crystalline barite, dolomite and calcite. 110 Creek, Mile 397, Alaska Hwy. (094-009) GSC 202886-C



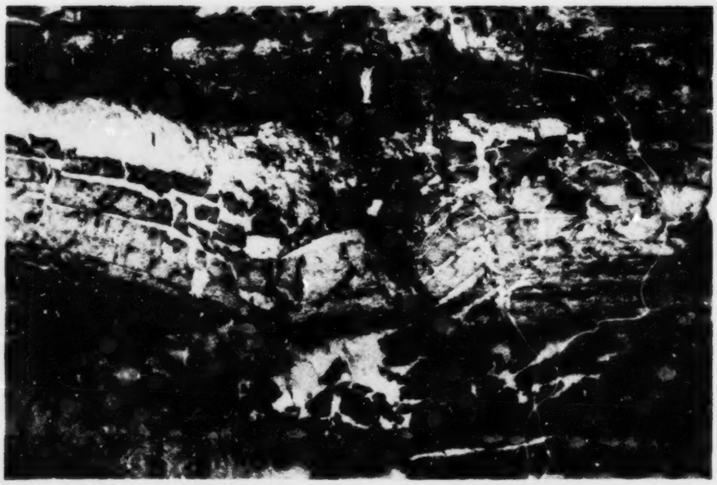


Figure 5B

Solution collapse breccia in limestone cemented by barite, dolomite and calcite. 110 Creek, Mile 397, Alaska Hwy. (094-009) GSC 202886-G

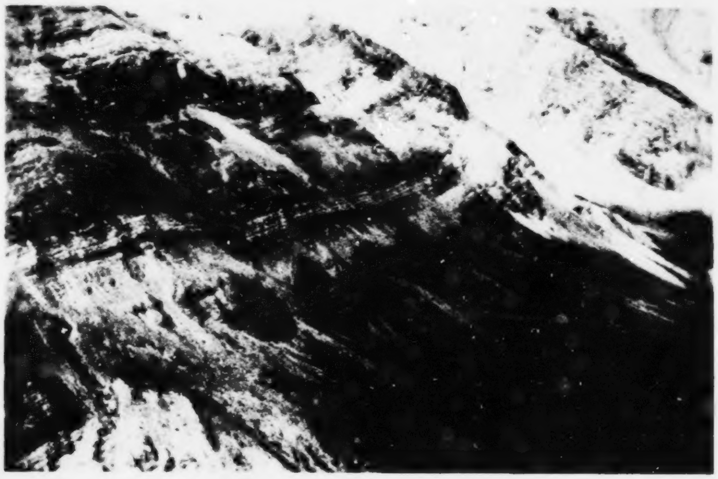
Barium for the bedded baritites may have been derived from a weathering landmass, from accumulations in seawater, from felsic igneous magmas as a late-stage differentiation product, from accumulations by scavenging organisms in the sea, or by chemical scavenging from clays in the vicinity of a thermal anomaly in the crust. Barium was probably transported in either chloride or bicarbonate solutions, or possibly in suspension on clay or iron hydroxide particles. The solutions and suspensions could have travelled either on the surface or in subterranean groundwater. The barium ion thus passed to the ocean was subsequently chemically or physically moved to bottom sediments or scavenged by planktonic life forms. Feces and skeletons enriched in barium contribute to the movement of the element to the ocean floor. Sulphate ions present in seawater reacting with barium ions in surface runoff contribute to strandline deposits in beach sands and gravels and at points where submarine springs emerge on the seafloor (Morrow, 1975; Morrow et al., 1976).

Convecting seawater near thermal anomalies in crustal shales would scavenge barium ions and the resulting exhalative solutions could emerge on the seafloor to deposit barite in marine clays and chert. Goodfellow et al. (1980) concluded, as a result of a geochemical survey, that the barium and other elements that occur in anomalous amounts in sections of the Road River Formation cherts and shales that contain bedded baritites, were supplied by an alkaline volcanic event. Alkaline flows and pyroclastic rocks are not always identifiable in these chert and shale sections. This mechanism is the one presently favoured by many geologists. The ore solutions must have had an unusually rich or large source of barium, or the depositional conditions must have been ideal for a long period of time, in order to account for the major tonnages of barite in stratiform bodies that are up to 30 m thick and have a lateral extent in excess of 1 km (e.g. Sulphur Creek, 94-13) (Fig. 6A, 6B). Moreover, the absence or low content of Cu, Pb, Zn, Hg, and Mo in these deposits suggests either that they were not formed in proximity to an igneous source of the ore solutions or that the combination of the state of oxidation of the ore solution, the availability of a suitable basin and the low sulphur content of the environment prevented the fixation of the heavy metal sulphides (K.M. Dawson, personal communication). In fact, the bedded baritites are usually but not always characterized by their low content of Fe sulphides.

Barium could equally well have been scavenged from sea water by an abundant planktonic population and settled to form part of the bottom oozes such as those in the modern equatorial Pacific and Atlantic oceans. Abyssal sediments underlying the equatorial belt of high organic productivity between latitudes 10°N and 10°S have up to 20 per cent more barium than similar bottom sediments outside of this zone.

Figure 6A

Distant view of massive white barite section 15 m thick extending from left foreground to the next major ridge. Sulphur Creek, B.C. (094-021) GSC 202886



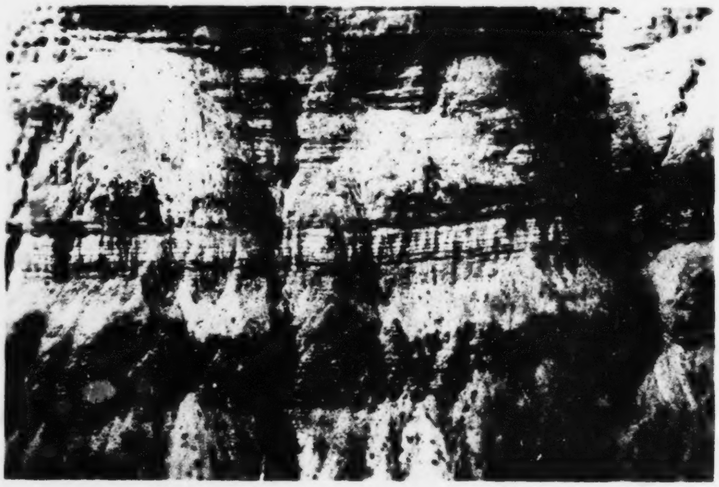


Figure 6B

Close-up of massive white barite section at the centre of the picture. Darker limestone interbeds show in the otherwise white bed. Sulphur Creek, B.C. (094-012) GSC 202886-A

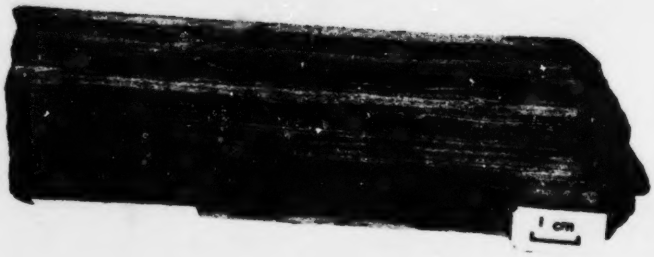


Figure 7A

Thinly laminated black chert and fine-grained barite. Collected on Rain-Snow Claims (106-001), Sekwi Mountain, map-area, District of Mackenzie. Collected by K.M. Dawson. GSC 203274-I

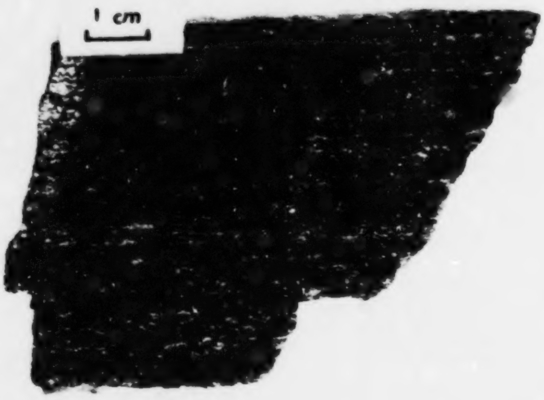


Figure 7B. *Laminated and nodular barite with black chert matrix. Flattened nodules combine to form more or less continuous laminae. Art Ekwi Claims south (105-C28), Sekwi Mountain, map-area, District of Mackenzie. Collected by K.M. Dawson. GSC 203274-M*

Maxima in barium content (one to two per cent) are reported in siliceous oozes surrounding areas of calcareous ooze and such concentrations are attributed to a combination of biological and chemical processes (Revelle et al., 1955). Arrhenius and Bonatti (1965) reported one to ten per cent barium calculated on carbonate-free basis. Species of the diatoms **Rhizosolenia** and **Chaeteroceras** abound in surface waters and their delicate frustrules contain anomalous amounts of barium (Brongersma-Sanders, 1966). The sinking skeletons of the dead diatoms rapidly dissolve but they carry barium towards the seafloor sediments. This may explain enrichment without organic remains to identify the means of conveyance. Trace amounts were probably carried down in the skeletons of marine plankton and, in areas where the rates of carbonate deposition and dissolution are high, the barium content of the sediments were increased. The carbonate skeletons of foraminifera and coccolihoporidae are practically free of barium but there is some evidence that the element is transported to the seafloor by fecal pellets. The element is preserves as barite or as barium adsorbed by clays, zeolites, manganese and iron oxides (Graf, 1960). Analyses of snail and clam shells and species of **Xenophyophora**, a group of deep water marine rhizopod foraminifera, indicate anomalous amounts of barium relative to sea water. However, according to Graf (1960) none of these species are considered significant conveyors of barium to abyssal sediments.

Bacterial action is also responsible, in seafloor anoxic sub-basins, for the dissolution and transport of barium (Bolze et al., 1974; Brongersma-Sanders, 1966). The sulphate, either as the ion in solution or fixed in barite, is reduced, and the sulphur thus freed becomes bound up in iron sulphides. Any barium taken into solution might also be adsorbed on clay or manganese oxide particles until more sulphate anions are introduced. Sulphate anions might be introduced by an influx of seawater, groundwater from buried evaporite beds, or exhalations from volcanic activity. Barite then reprecipitates as nodules, lenses and bedding laminae in the bottom ooze as part of the normal sedimentation process. In summary, the author believes the bedded barite deposits are the product of sedimentary processes regardless of the original source of barium and sulphate ions.

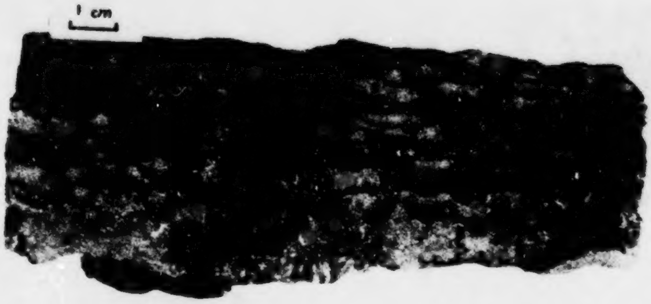
The silica-rich carbon-poor baritite variant is illustrated by several occurrences in Stevens County, Washington State, (Mills et al., 1971; Moen, 1964; Fig. 10A, 10B, 11B). Greystone Mine, Battle Mountain, Nevada (Zimmerman, 1969; Ketner, 1963; Fig. 9A, 9B) and by the Moose showing (105-20) (Dawson, 1977; Lydon et al., 1979; Fig. 11A). These deposits are characterized by nearly pure barite in beds that vary in thickness from less than one millimetre to several millimetres (Fig. 11B). The laminae are conformable with the enclosing beds and in folded sections behave like normal fine grained sedimentary rocks (Fig. 9A, 9B). Locally, they pinch into boudins on the limbs of folds (Fig. 10A, 10B) or slip into saddle-shaped bodies on the crests or in the troughs of folds (Mills et al., 1971). Locally, the barite beds have been recrystallized near late faults and the dark grey to black colour due to dispersed amorphous carbon has been destroyed. Elsewhere, barite sections have been intruded by felsic to intermediate intrusive rocks and both barite and the enclosing sediments have suffered contact metamorphism.

The carbon-rich, moderate to high silica variant is illustrated by several occurrences in the Sekwi Mountain and Niddery Lakes Map-areas near Macmillan Pass, Yukon Territory and District of Mackenzie and in the Meggen deposit, Federal Republic of Germany. The Canadian examples include the Tea (105-19), Tom (105-24) and Wise (105-28) properties (Blusson, 1971; Blusson and Tempelman-Kluit, 1970; and Dawson, 1977). These deposits are characterized by: (1) barite laminae and (2) barite nodules in either black shale or chert matrix. The barite laminae range in thickness from less than one millimetre to several millimetres with, the lateral extent measured in metres (Fig. 7A).

The nodular baritites are illustrated by the Art-Ekwi claim (105-30, -33) (Fig. 7B); Wise claim (105-28) (Fig. 8A); Rain-Snow claims (105-1) (Fig. 7A) and the Tea claims (105-19), (Fig. 7B, 8B). The barite nodules occur in conformable bands that grade across section or along strike

Figure 8A

Nodules and flattened nodules of barite coalesced in one bed. The intervening material is black chert. Wise Claims, Twitya River, District of Mackenzie. (105-026) GSC 203274-E



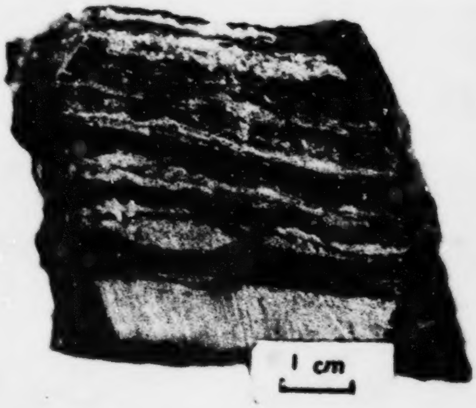


Figure 8B. *Flattened barite nodules and irregular beds of flattened nodules interlaminated with black chert. Tea Claims, Niddery Lake map-area, Yukon. (105-081) GSC 203274-C*

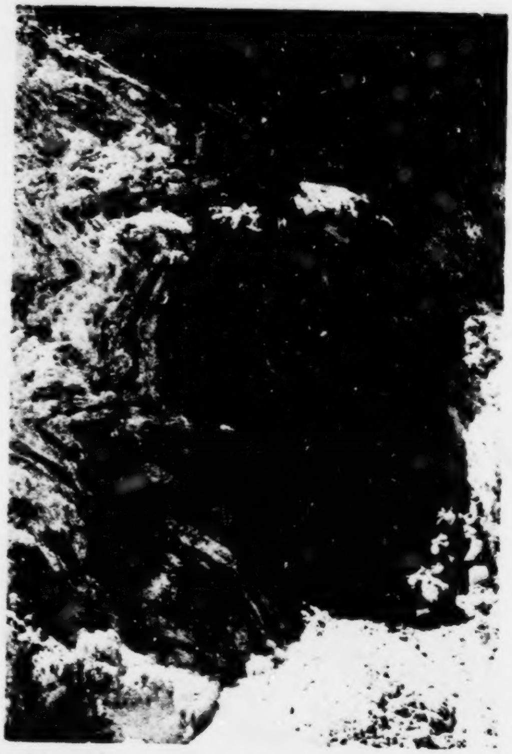
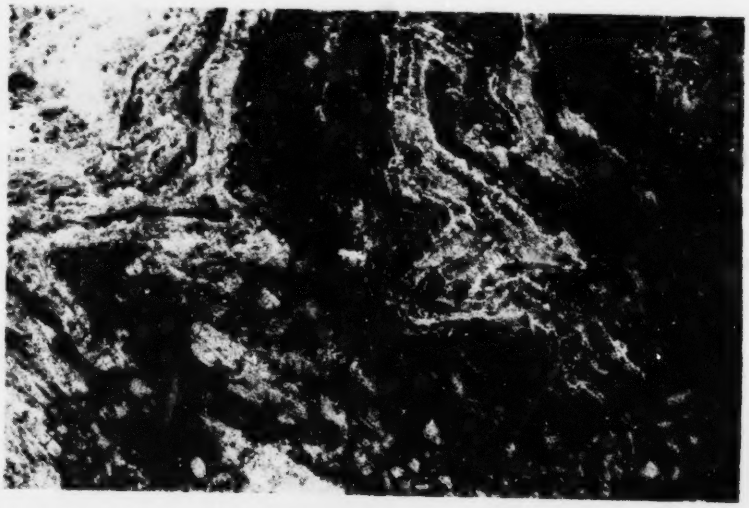


Figure 9A. *Distant view of highly folded barite-siliceous argillite section. Exposed in the open-pit, Greystone Mine, Battle Mountain, Nevada. GSC 202886-U*

Figure 9B

Close-up view of highly folded barite-siliceous argillite section. Exposed in the open-pit, Greystone Mine, Battle Mountain, Nevada. GSC 202886-M



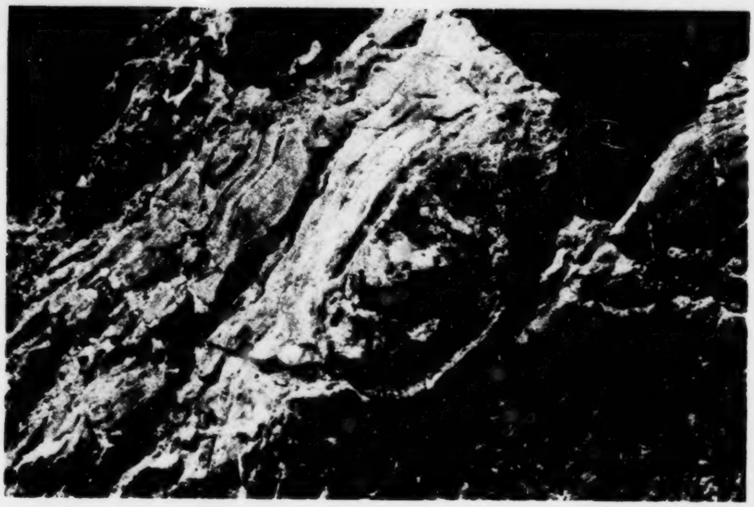


Figure 10A

Barite boudin in interbedded barite and siliceous argillite, Stevens County, Washington, State. GSC 202886-W

Figure 10B

Folded baritite and siliceous argillite, Uribe Property, Stevens County, Washington, State. GSC 202886-Q

into interlaminated barite and chert (Fig. 8A). The nodules range from crystalline aggregates several millimetres across to flattened nodules or laminae less than one millimetre across. Typically, the deposits are black to dark grey, foetid, thinly bedded and intercalated with grey to black shale or chert. A variety of small-scale sedimentary textures and structures suggest rhythmic deposition of barite and chert or silt as seafloor muds. Laznicka (1976) in his study of barite nodules from this area, concluded they were late diagenetic rather than synsedimentary.

Tom Deposit. The Tom deposit (105-24) of Hudson Bay Exploration and Development Company is located east of the Canol Road near Macmillan Pass, Yukon Territory about 232 km northeast of Ross River (Fig. 12). Underground development and diamond drilling has proven reserves of 8 817 000 tonnes containing 77.95 g/t Ag; 8.4% Zn, 8.1% Pb with 30% barite as the chief gangue mineral (Carne, 1976). The Tom deposit occurs within the Devonian strata of the Canol Formation (Carne, 1976, 1979; Fig. 12) which are overlain by the Mississippian Imperial Formation. Both formations have been intruded by Cretaceous quartz-feldspar porphyry dykes and granite stocks. Carne subdivided the Canol Formation into four units: 1, 2, 3a and 3b and he positioned the barite-lead-zinc mineralization between the last two (Table 17).

Unit 1 of the Canol Formation contains four distinctive lithologies in the upper 45 m, including: a) interbedded silty shales and sandy siltstone; b) thick bedded silty sandstones; c) medium- to thick-bedded sandy siltstones; and d) chert pebble conglomerate bodies with lenticular cross sections.

Unit 2 is characterized by resistant beds that form ridges and scarps in the vicinity of the Tom deposit. They consist mainly of massive, chert-pebble conglomerate and less resistant, coarse grained chert turbidites with interbedded recessive black silty shales. The coarser members are well indurated and jointed.

Unit 3a is well exposed on the eastern part of the Tom property and consists mainly of thin bedded porous, silty sandstones and minor laminated black pyritic shale. The sandstone beds range in thickness from a few millimetres to approximately 0.5 m. The beds and laminae pinch and swell along strike and are marked by scour marks and flute casts.

Unit 3b rocks are silvery grey weathering, very siliceous and carbonaceous black shales. Exposures are limited mainly to the siliceous members. Minor intraformational conglomerate and contorted beds occur near the base of the unit. East of the Tom orebody the unit consists of uniformly fine grained carbonaceous shale with a few coarse clastic beds. The beds range from thin and platy to thick and massive.

The overlying Lower Mississippian Imperial Formation has been divided into units 4a and 4b (Carne, 1979). The regional bedded baritite occurs between these two units. The rocks of unit 4a weather a distinctive buff brown colour in contrast to the silvery grey Canol rocks and the dark brown overlying unit 4b. The lowest members of unit 4a include interbedded very fine grained black mudstones and shales. Some mudstone beds contain spherical anhydrite-barite nodules that range from a few millimetres to more than 2 cm in diameter. Other beds in the unit contain bladed gypsum casts suggesting periods of evaporite conditions.

Unit 4b consists of a monotonous series of resistant, cliff-forming, brown weathering silty mudstones. Bed surfaces commonly show ripple marks. Detrital minerals include quartz, sericite and carbonaceous material.

Orange-weathering quartz-feldspar porphyry dykes occur south of the Tom property and cut the underlying sedimentary rocks. A small area of weakly-hornfelsed sedimentary rocks occurs in the southeast corner of the property adjoining a granite stock.

The structures of the Macmillan Pass area include folds, faults, and domes, resulting from either cyptovolcanism or the intrusion of small granite stocks. Folds in the sedimentary rocks include easterly-trending isoclinal folds and northwesterly-trending open folds that are the main features of the tectonic pattern. The Tom orebodies occur in a north-trending fold that is cut by a north-trending, west-dipping, thrust fault. Locally, the attitude of the sedimentary rocks at the south end of the west orebody is influenced by intrusion of granite stocks south of the property (Dawson, 1977; Carne, 1979; Lydon, et al., 1979).

Table 16. Table of formations in the vicinity of the Tom Deposit, Yukon Territory

Formation	Map Unit	Lithology	Approximate Thickness (metres)
CRETACEOUS		Quartz-feldspar porphyry dykes, stocks	
		hornfels	
MISSISSIPPIAN IMPERIAL FORMATION			
	4b	Bioturbated, calcareous and noncalcareous crosslaminated silty mudstone and muddy siltstone	>1000
	4a	Bioturbated mudstone, shale, siltstone, flat-pebble conglomarate and minor tuffaceous shale	0-100
UPPER DEVONIAN CANOL FORMATION			
	3b	Black pyritic shale; minor black siliceous mudstone, calcarenite turbidites and black fetid limestone.	30-1300
		Stratiform barite-lead-zinc-silver deposit (Tom)	0-20
	3a	Pyritic shale, siltstone, pebbly mudstone, intraformational conglomerate, slump deposits and turbidites	4-40
	2	Massive chert-pebble conglomerate, (flow debris and turbidites)	45
	1	Siltstone and shales (turbidites), minor lensoid chert pebble conglomerate (debris flows)	120

Source: Carne, 1979.

Table 17. Summary of the mineralogical phases in the south end of the west ore zone, Tom property.

Ore minerals	Accessory ore minerals	Gangue minerals	Form	Distribution
1. galena, sphalerite, pyrite, siderite	chalcopyrite, bournonite, boulangerite, tetrahedrite	quartz, barite	massive to poorly laminated, 2.5 m to 3.5 m thick	at base, south end of west zone
2. sphalerite, galena, pyrite		chert, barite	evenly laminated black cherty argillite, and baritite, 2.4 m thick	base of most of west zone, equivalent of no. 1
3. sphalerite, galena, pyrite		cherty barite	lense shaped body of laminated argillite and baritite	overlies no. 1 at south end of west zone
4. barite, sphalerite, galena			thinly laminated 6.5 to 23.5 m thick	south end of west zone
5. witherite, baritocalcite, barite	galena, sphalerite, pyrite, chalcopyrite	cherty	contorted and disrupted argillite laminae, 15.3 m thick.	
6. galena, sphalerite, pyrite		chert	elongate saucer-shaped body, interlaminated black argillite and baritite, 9.5 m thick	lateral equivalent of no. 5 overlies no. 4
7. sphalerite, galena, framboidal pyrite			thinly laminated siltstone, black argillite, minor chert, 5.0 m thick	caps the west zone

Source: Carne, 1979.

Barite-lead-zinc mineralization occurs in two bodies on the Tom property (Fig. 12; Table 16). The east zone is 160 m long, 3 m to 20 m wide and dips steeply west. The west zone is 1200 m long and 3 to 60 m thick and dips 60° to 70° west. Carne (1979) has studied mineralization patterns in the southern part of the west zone and found that the mineralization occurs in a breccia zone (Table 17).

Meggen Mine. The Meggen Mine in the Lenne Valley, 70 km east of Cologne, West Germany (Fig. 13) is a well-studied example of the bedded pyrite-barite type (Buschendorf and Puchelt, 1967; Gwosdz et al., 1974; Zimmerman, 1970). The mine is near the village of Meggen on the Lenne River, State of Nordrhein-Westfalen. The barite-sulphide bed ranges in aggregate thickness up to seven m but the ore zone is built up of thin individual layers and lenses of mainly fine-grained barite or sulphides thinly interlayered with carbonaceous material and dark fissile shale. The ore, which consists of barite-sulphide (pyrite, marcasite, sphalerite and some galena), occurs in a bed that lies conformably in a Middle Devonian sedimentary sequence (Table 17). The latter consists, in part, of slightly-metamorphosed shales of the Rheinisches Schiefergebirge province that includes rocks of Devonian and Carboniferous age. Deposition took place during the Givetian Stage of the Devonian in closed basins on the floor of a shallow sea that had a few carbonate reefs and received fine grained clastic sediments from the surrounding landmass. Bioclastic limestone was deposited on the flanks of the reefs. The host rocks are detrital sediments and consist of well-sorted shale or argillite that were deposited in an anaerobic environment. This environment reuslted in preservation of a very high carbon content in the rocks.

The "Meggen Ore Bed" lies conformably at the top of the middle Devonian section and grades laterally into limestone (Fig. 13). The top of the ore bed is marked by a tuff or tuffite bed overlain at the mine by an Upper Devonian **Stringocephalus** limestone (Table 18). Sandy slates or shale with sandstone and thin limestone beds and lenses conformably underlie the "Meggen Ore Bed". The major structural features near Meggen are the northeast trending Meggen and Elspe synclines. The first is the smaller of the two and strata of its south flank, as well as those of the Elspe, are steeply inclined and locally overturned. The ore bed occurs in the Meggen syncline and on the south flank of the Elspe syncline. Minor cross faults locally displace the ore horizon.

The ore forms a stratigraphic sequence that includes: (1) a large inner lens of layered sulphides of iron, zinc and minor lead that graded, on the average 72% FeS_2, 11% ZnS and 1% PbS (Gasser, 1974); (2) a thin transition zone less than 1 m thick between the sulphides and the barite; and (3) a zone of layered barite that grades laterally into sulphides and/or limestone at the periphery of the deposit. The ore exhibits a variety of textures and structures. The main features of the barite are the fine grained lumps of the mineral with nearly planar lower surfaces and curved upper surfaces. The intervening spaces are occupied by lenses of barite that lap onto the lumps. Some of these have curved bottoms and the texture is emphasized by shale and carbonaceous films. Some of the barite lenses are crossed by stylolites filled by black or brown clay. Barite has locally been recrystallized to coarse-grained nodular aggregates. The massive sulphides occur in multiple, stacked lenses, the lower sides of which are curved or irregular and the top sides are flat. The lensoid structure of the barite and the sulphides is similar to that observed in shallow water sediments where currents are active and evaporites may be forming. The source of the barite and metallic sulphides may be either sedimentary or volcanogenic but the genesis of the deposit is attributed to syngenetic proceses operative in euxinic basins on the floor of a shallow sea.

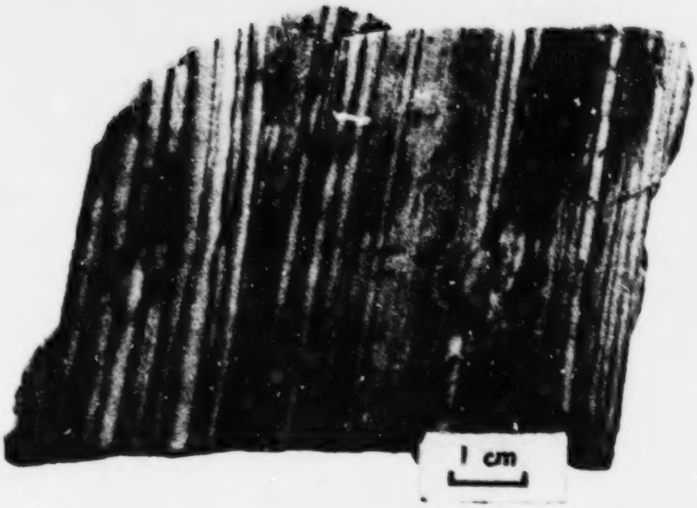


Figure 11A

Interlaminated siliceous argillite and fine-grained barite. Moose Property, Canol Road, southeast of Macmillan Pass, Yukon. (105-020) GSC 203274-H

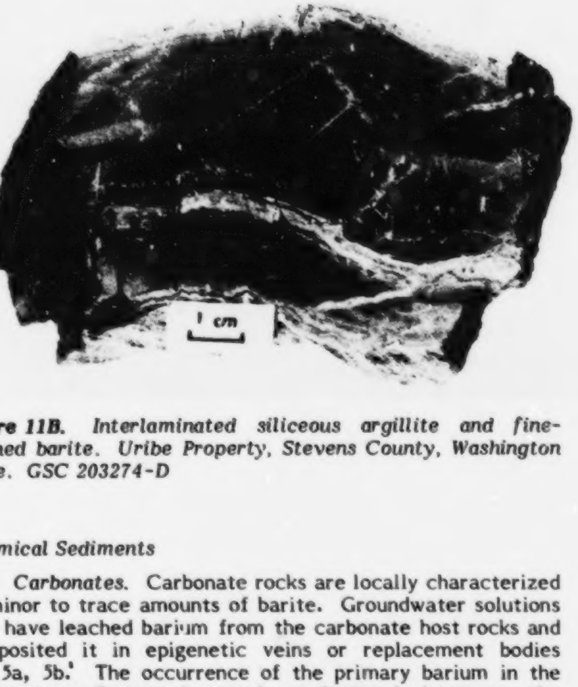


Figure 11B. *Interlaminated siliceous argillite and fine-grained barite. Uribe Property, Stevens County, Washington State. GSC 203274-D*

Chemical Sediments

Carbonates. Carbonate rocks are locally characterized by minor to trace amounts of barite. Groundwater solutions may have leached barium from the carbonate host rocks and redeposited it in epigenetic veins or replacement bodies Fig. 5a, 5b.[1] The occurrence of the primary barium in the carbonate sediments is poorly understood; however, the barium content of certain carbonate rocks coincides with the clay content and the element may be transported adsorbed on clay particles. Subsequently pore fluids or ground waters may have collected and transported barium in solution to barite deposition sites.

In Canada barite occurs in northeastern British Columbia as clasts in a dolomite-barite conglomerate and as conformable massive beds in a Middle Devonian carbonate sequence. Three sites in this region illustrate these types of occurrence. Near the head of Mile 472 Creek, Alaska Highway, barite and dolomitic limestone clasts occur in a conglomerate at the contact between the Lower Devonian Wokkpash Formation and the overlying Middle Devonian Stone Formation. The conglomerate represents the upper part of a deeply weathered and oxidized zone (Taylor and MacKenzie, 1970).

The massive barite beds are conformable with the dolomitic host rock at the Mile 472 Creek stratigraphic position immediately above the Wokkpash Formation and at the base of the Stone Formation. A number of individual beds at Sulphur Creek (Fig. 6A, 6B) (Morrow et al., 1976), ranging from one to several metres in thickness, are combined in an aggregate section 15 m thick that has a horizontal extent exceeding 1 km. The barite is interbedded with grey dolomitic limestone and where it is most abundant it forms the major part of the local sequence. The barite is coarse- to fine-grained, white, and crystalline, and carries minor to trace amounts of interstitial calcite and fluorite. According to Morrow (1975, p. 265): "the only place where barite forms a predominant rock constituent is at Sulphur Creek. Here, the basal 15 m of the Stone Formation consist of medium-bedded white barite with minor dolomite. No bedded barite has been observed elsewhere.

The stratigraphic and geographic position of this barite deposit suggests that it formed at the base of the seaward edge of the fluctuating fresh groundwater-seawater interface in the Devonian paleoaquifer."

Hydrocarbons. Hydrocarbon fuels (oil, gas and coal) contain amounts of barium often in excess of crustal averages (Puchelt, 1972). The form of occurrence of the element in fuels in uncertain but available evidence suggests that it is adsorbed on clay or humic acid components in coal and is in metallo-organic compounds in oil. Although some English coals contain more than five percent Ba in ash, this is attributed to epigenetic enrichment (Reynolds, 1939) and it is unlikely that fuels will be a viable source of barium.

Brines

Barium-rich brines have been identified in an oil field off the California coast; in deep wells near Salton Sea, California; in the Atlantis II Deep of the Red Sea; and in the Coal Measures of Great Britain. Barium-rich oil field brines in California and elsewhere in the United States increase the cost of oil and gas recovery by blocking the collection pipes and valves and thus necessitating more frequent cleaning or replacement (Gates and Caraway, 1965). In the California field this had been attributed to barite precipitation at points where artificially introduced seawater first encountered the oil field brines, but subsequent research suggests that other physical and chemical conditions were responsible (Vetter, 1975). These have subsequently been largely corrected by modifications to the collection structures. Anomalous barium content is reported in brines from deep wells near Salton Sea, California (Puchelt, 1972). Such water is potentially toxic for human consumption and hazardous to use for irrigation purposes. The barium-rich brine of the Atlantis II Deep, Red Sea, is of scientific interest because it may be related to sulphide deposition on the floor of the deep. Several coal mines in Durham and Northumberland Counties, England have barium-rich brines (Collins, 1972; Thomas, 1973; Edmunds, 1975). The brine from the Eccles Pit, Backworth, Northumberland was collected and treated with sulphate-bearing chemicals to produce blanc-fixe (chemically precipitated barite) for commerical purposes.

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[1] see Fig. 5, page 38

Epigenetic Deposits

Epigenetic mineralization occurred subsequent to the consolidation of the wall rocks in a variety of structures or as a replacement of the wall rocks (Table 19). Epigenetic deposits are presently the main source of barium minerals in Canada. Fissure filling, epigenetic deposits occupy voids resulting from mechanical deformation, including dilatant zones along faults and folds, gash fractures, joints and bedding planes. Shear and breccia zones along faults are common sites of deposition. Solution cavities in chemical sedimentary rocks are also typical sites for subsequent mineral deposition.

Table 18. Generalized table of formations of the Meggen basin, Federal Republic of Germany

Era	Period or epoch	Formation	Lithology
Paleozoic	Upper Devonian Frasnian	Kiesbandzonen	Greenish, grey to dark grey shales with limestone bands and nodules, locally tuff bands and pyrite lenses
		Lagerkalk	Pelagic limestone
	Middle Devonian Givetian		Tuff, tuffite marker horizon
		Meggen ore bed	Barite-pyrite-sphalerite ore
		Meggen beds	Reef, detrital limestone cut by numerous sedimentary dykes
		Odershausen limestone	Limestone
	Eifelian	Tentaculite bed	Shale
		Wissenbacher shale	Shale

Source: Krebs, 1972.

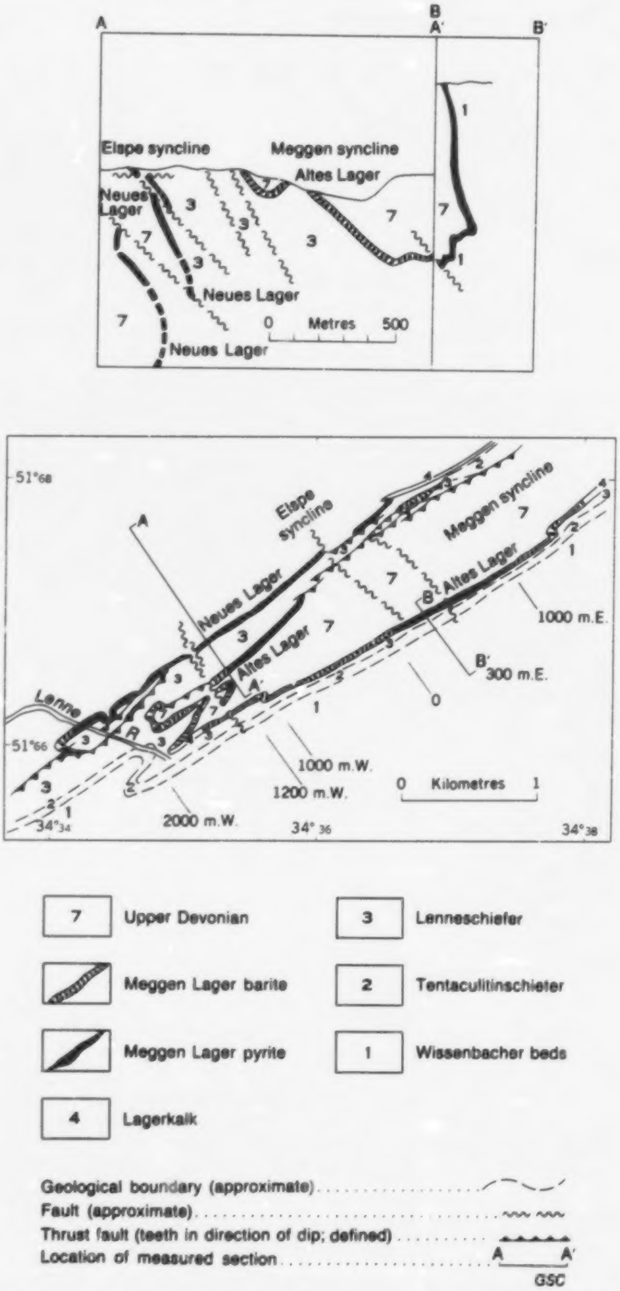

A
B
A'
B'
1
Elspe syncline
Meggen syncline
Altes Lager
Neues Lager
3
7
0 Metres 500
51°68
51°66
Elspe syncline
Meggen syncline
Neues Lager
Altes Lager
Lenne
1000 m.E.
300 m.E.
1000 m.W.
1200 m.W.
2000 m.W.
0 Kilometres 1
34°34
34°36
34°38
7 Upper Devonian
Meggen Lager barite
Meggen Lager pyrite
4 Lagerkalk
3 Lenneschiefer
2 Tentaculitinschiefer
1 Wissenbacher beds
Geological boundary (approximate)
Fault (approximate)
Thrust fault (teeth in direction of dip; defined)
Location of measured section
GSC

Figure 13. Geological sketch and composite cross-section of the Meggen barite-pyrite-sphalerite deposit, Federal Republic of Germany.

Table 19. Classification of epigenetic barium deposits

CLASSES	EXAMPLES
Fissure Fillings	Brisco (82-42) and Parson (82-44), B.C.; Thunder Bay District and Yarrow Mine (41-15), Ont.; Lake Ainslie East, N.S.; and Collier Cove (01-72), Nfld.
Replacement Deposits	Mineral King (82-34) and Silver Giant (82-43), B.C.; Walton Mine (21-13), N.S.

Textural and mineralogical evidence, such as mineral banding suggests deposition at low to moderate temperatures and pressures. Evidence of an igneous source for the ore solutions is rare and in most cases they were probably derived from the sediments through which the solutions travelled. A common interpretation is that this process took place at water table level in a karst environment developed beneath an unconformity. Mineral-depositing solutions penetrate limestone or dolomite collapse breccias and the results range from complete cementation to thin mineral crusts on the fragments coupled with many unfilled voids. In a few localities mineralized veins are spatially associated with granite intrusions and these probably represent deposition of materials derived from the nearby intrusion under conditions of higher temperature and pressure.

Fissure Fillings

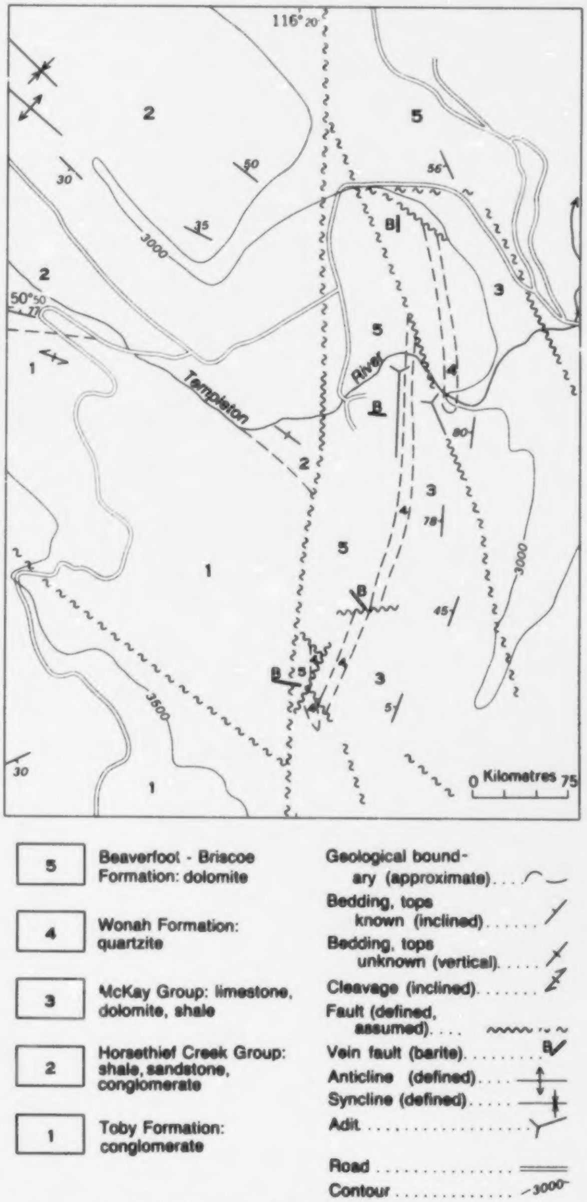
Barite has been produced from epigenetic vein deposits in British Columbia, Ontario, Nova Scotia and Newfoundland (see Table 19). In British Columbia barite occurs as a gangue mineral in a former lead-zinc-silver-gold producer, the Silver Tip (104-04) property near Alice Arm (Fig. 14). The Brisco (82-42) and Parson (82-44) mines in southeastern British Columbia have been in production for thirty years. In Ontario, the Silver Mountain (52-13), Yarrow Township (41-15) and Premier Langmuir (42-06) mines were small Ontario barite producers. The Lake Ainslie East area, Nova Scotia, was an epigenetic vein source of barite as was Colliers Cove (01-72) in Newfoundland.

British Columbia

Brisco Mine. South of Golden, British Columbia, barite has been mined from typical epigenetic vein deposits (Fig. 15). The best known is probably the Brisco deposit, located 6.9 km west of Brisco (Fyles, 1959b; McCammon, 1964). The main orebody at Brisco occurs in a north-striking breccia zone in massive, grey dolomite of the Ordovician to Silurian Beaverfoot Formation. The orebody occurs within the east limb of a syncline that trends north from Steamboat Mountain (Fig. 15). The Mount Forster-Steamboat thrust fault passes west of the Brisco claim group, and on the property a younger, west-trending, sinistral fault offsets the host dolomite to the southeast. Elsewhere in the mine area a number of smaller faults contribute to the structural complexity of the main orebody.

The main Brisco orebody has an average width of 7.5 m, a maximum width of 12 m, a vertical depth of 80 m and a strike length of 234 m. The orebody strikes north and dips steeply west. The ore zone pinches and swells along strike, resulting in an irregular distribution of individual high-grade barite lenses. The wall rocks are brecciated dolomite cemented or veined by individual high-grade barite lenses. The ore is nearly pure barite, locally diluted by horses of dolomite. The west wall rock is highly fractured dark grey to black dolomite with a few small lenses and veins of barite. The initial Brisco production came from an open pit which was later (1958) phased into an underground operation conducted from an adit driven beneath and east of the original open pit quarry. More recently a decline was driven beneath the old adit to permit mining to a greater depth.

Parson Mine. The Parson (82-44) barite mine is in the same general area and is characterized by high grade barite in dilatant zones in faulted carbonate and/or shale


116°20'
2
5
30
50
35
56
3000
B
2
50°50'
27
3
5
1
Templeton
River
4
B
80
2
3
78
4
5
1
B
3000
45
B
3
5
3500
30
1
0 Kilometres 75
5
Beaverfoot - Briscoe Formation: dolomite
4
Wonah Formation: quartzite
3
McKay Group: limestone, dolomite, shale
2
Horsethief Creek Group: shale, sandstone, conglomerate
1
Toby Formation: conglomerate
Geological boundary (approximate)
Bedding, tops known (inclined)
Bedding, tops unknown (vertical)
Cleavage (inclined)
Fault (defined, assumed)
Vein fault (barite)
B
Anticline (defined)
Syncline (defined)
Adit
Road
Contour
3000

Source of information: British Columbia Department of Mines Annual Report; p. 194, fig. 22 1964

GSC

Figure 15. *Geology and Table of Formations, Brisco barite mine, Invermere, British Columbia.*

wall rocks. The deposit consists of two parallel veins 100 m apart, striking northerly and dipping 45 to 65° west. The country rocks are Lower Cambrian interbedded quartzite, dolomite and shale. Both veins are bounded by well defined fault planes. The west vein is exposed in one quarry for a length of more than 70 m and ranges from 4 to 10 m in width. The east vein is exposed in quarries and adits for a total length of 200 m and a maximum width of 12 m. A few relatively large horses of country rock are present in both veins.

The barite is white to creamy white, coarse-grained and compact. The vein contains impurities consisting of quartz, hematite, pyrite, chalcopyrite, siderite and calcite. Vugs are common. The purity of the barite ore is demonstrated by the high average specific gravity of 4.30.

Ontario

Epigenetic barite deposits in Ontario have been subdivided into three classes on the basis of their mineral contents: 1. silver veins (Franklin, 1970); 2. lead-zinc-barite veins (Franklin and Mitchell, 1977) and 3. barite veins. Barite has been mined from types 1 and 2 in the Thunder Bay District and from type 3 in the Timiskaming District of northeastern Ontario. The veins occur in a variety of dilatant structures that have been filled by minerals precipitated from solutions bearing heavy elements derived from igneous or nearby wall rock sources. High grade barite veins are more widespread than those in which barite is a gangue mineral with silver, galena, sphalerite, pyrite and chalcopyrite. Silicate and carbonate minerals, in variable amounts, occur as gangue minerals in the high grade barite veins.

Thunder Bay Barite veins. The Thunder Bay baritiferous veins were originally prospected for their silver or base metal contents (Tanton, 1931; Franklin, 1970; Fig. 16). The producing areas are underlain mainly by flat lying Proterozoic shales intruded by Keweenawan diabase sills and dykes and cut by nearly vertical faults having limited displacement. Locally, dilatant zones, breccia zones and shears along faults have been filled by sulphide minerals and barite. Barite, quartz, calcite, fluorite and rock fragments are nonsulphide constituents in both silver-rich and lead-rich vein-types. The vein mineralization is interpreted as a product of intrusion of the Keweenawan diabase (Franklin, 1970).

Four properties in the Thunder Bay District are past producers of silver; Creswel (Porcupine) Mine (52-25); Silver Islet (52-33); Beaver Mine (52-31) and Silver Mountain Mine (52-13). Barite was produced from the west end of the Silver Mountain vein and the vein on South McKellar Island (52-09) (Fig. 16). The baritiferous lead veins are illustrated by the Dorion Mine (52-84) vein (Hawley, 1930).

Yarrow Barite Mine. The Yarrow barite mine (41-15), west of Matachewan Ontario, continues to produce (1982) a few thousand tonnes of barite a year from fissure fillings in Aphebian, Gowganda arkosic conglomerate (see Fig. 18A, B).

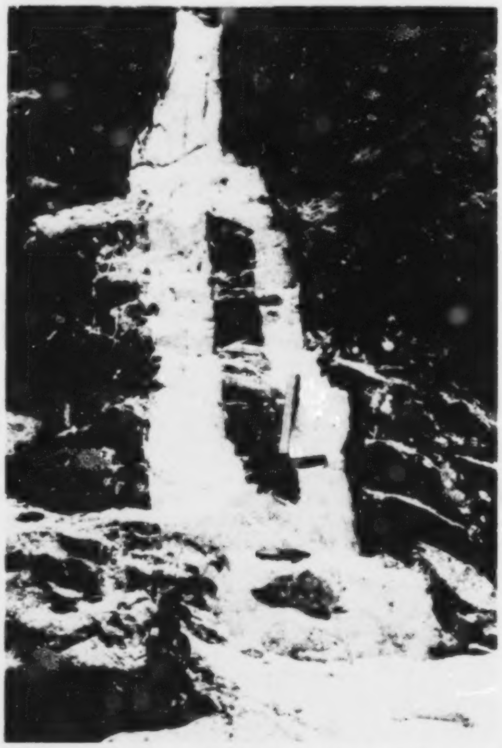


Figure 18A. *Extender Minerals Ltd., barite vein in Gowganda arkosic conglomerate. Yarrow Township, Ontario. (041-013) GSC 202031-B*

Figure 18B

Barite vein in Gogama arkosic conglomerate, Yarrow Township, Ontario. (041-013) GSC 202031-C

Massive to banded barite, the sole product of the operation, fills fissures in a regional joint system. Where several barite-filled vertical joints occur in close proximity they result in mineable widths. Locally, dusty hematite and traces of chalcopyrite are reported. Quartz, calcite and angular rock fragments are the main contaminants of the ore.

Nova Scotia

Lake Ainslie Barite Veins. Examples of epigenetic barite veins in Nova Scotia are those in the Lake Ainslie East area, a source of barite between 1890 and 1916 (Fig. 17; Zurowski, 1972; Binney, 1975; Norman, 1935). Two north-trending elliptical inliers of Lower Paleozoic and Proterozoic rocks are surrounded by Middle to Upper Mississippian beds along the east side of Lake Ainslie. The most significant barite deposits occur in one of these inliers on the southeast shore of the lake.

The George River Group of rocks, the oldest in the area (see Table 20), consists mainly of buff coloured, schistose quartzite and crystalline marble. The marble is locally a talc-serpentine schist with a regional northeasterly-trending schistosity that may parallel axial planes of fold predating the intrusion of Devonian granites (see below).

Devonian granites intrude the rocks of the George River Group. They include grey, medium- to coarse-grained granodiorite and diorite locally characterized by numerous quartzite and limestone inclusions. Other, smaller felsic dykes and stocks near Lake Ainslie have been related genetically and chronologically to the Devonian granites (Norman, 1935). As far as known neither the Devonian granites nor the associated felsic dykes contain barite-fluorite veins.

The Fisset Brook Formation consists of basal conglomerate, quartzitic and lithic wackes, andesite flows, minor nonvolcanic and volcano-sedimentary rocks, welded rhyolite tuffs, lapilli tuffs and tuff agglomerate. It overlies unconformably both the George River Group and the Devonian granites and comprises the basal unit of the Horton Group. The Fisset Brook Formation is exposed in two inliers, east of Lake Ainslie between Scotsville and Trout Brook, but between these inliers it is hidden beneath upper Horton sediments along Glenmore Brook.

The upper Horton Group, overlying the Fisset Brook Formation, consists of massive, grey arkose (1800 m) and a pebble conglomerate with beds from a few metres to 15 m thick. In addition there are thin interbeds of grey or red shale and the latter contains many yellow calcite concretions.

The orebodies at Lake Ainslie East are tabular fissure fillings in faults that cut the George River Group and Fisset Brook Formation in the northern inlier but only the latter in the southern inlier (Creed, 1968). The Campbell (11-46) MacMillan (11-48) vein (Fig. 17) has been traced for 420 m, with widths up to 18 m and a depth of 180 m. The orebody pinches and swells and exhibits minor rolls along strike and down dip. This vein is estimated to contain reserves of 3 298 600 tonnes grading 27.82% barite and 18.95% fluorite. In addition to the Campbell-MacMillan, the principal mineralized veins include the Moore (11-50), D.J. MacDougall (11-49), A.J. MacLean (11-44), Upper and Lower Johnston (11-41) and J.A. MacDougall (11-47). Total reserves for the area exceed 4 436 000 tonnes (Zurowski, 1972). However, eastward and westward extensions of some veins have not been traced and additional reserves are possible. In addition, the possibility of discovery of new blind veins in the camp is significant.

The veins vary in colour and texture and in the relative proportions of barite and fluorite. They contain maximum barite content near the present surface and decreasing amounts at depth, whereas the fluorite shows a reverse distribution. Gangue minerals include calcite, minor manganiferous limonite, pyrite and chalcopyrite. The veins are weakly banded and locally vuggy and vein walls are encrusted with comb barite. In some veins angular fragments of wall rock dilute the mineralization. The barite is pink to white, and is mainly massive but locally occurs in comb aggregates and rosettes. It contains traces of strontium, iron and titanium. The associated fluorite ranges from green to colourless. There is weak wall rock alteration which may be because deposition of ore was under conditions of low temperature and pressure. Multiple stages of mineral deposition are illustrated by combinations of fluorite-barite-calcite. The mineralization is epithermal, deposited either from volcanogenic exhalations following deposition of the Fisset Brook rocks or from saline connate waters charged with barium and fluorine extracted from adjoining rocks and the overlying Windsor evaporites.

Newfoundland

Barite veins in Newfoundland have rarely been worked commercially. A few thousand tonnes of barite were produced from the Collier Cove vein (01-72), near Thornlea. White and pink, coarse bladed barite crystals 5 cm across occur in a vein that has been traced for 90 m and has an average width of 6 m. The wall rocks are arkose and conglomerate of the Hadrynian Snows Pond Formation. Reserves are too small to be economic. Other epithermal barite veins have also been reported in the Thornlea area.

Table 20. Table of Formations, Lake Ainslie East barite producing area, Nova Scotia

Era	Period or epoch	Formation	Lithology
Paleozoic	Mississippian	Windsor Group	Limestone, gypsum, shale and sandstone
		Horton Group	Sandstone, shale, conglomerate, arkose, minor limestone
		Fisset Brook Formation	Intermediate to felsic flows, tuffs, agglomerate and welded tuff
		Unconformity	
	Devonian		Granite and diorite
		Intrusive contact	
Proterozoic	Hadrynian	George River Group	Quartzite, schist and gneiss

Source: Zurowski, 1972.

Replacement Deposits

Replacement barite deposits in Canada occur in British Columbia, New Brunswick, Prince Edward Island and Nova Scotia, mainly in clastic and carbonate sedimentary rocks and, rarely, in volcanic rocks. Most past Canadian barite production has come from the large replacement body in the Walton Mine (21-13), Nova Scotia. Byproduct barite is also recovered (1979) from tailings of two abandoned base metal mines – Mineral King (82-34) and Silver Giant (82-43) – in southeastern British Columbia.

British Columbia

Mineral King. The Mineral King deposit (82-34) (see Fig. 19; Table 21) is 15 km west of Athalmer, 84 km south of Golden, British Columbia, on the south side of the ridge between Jumbo and Toby creeks. The orebodies consist of replacement lodes of barite, sphalerite, galena and pyrite in dolomite. Base metal production ended in 1967 but in 1965, 8210 tonnes of barite was mined from the upper part of the mine. Mountain Minerals assumed control in 1968 and commenced production of barite from the tailings ponds which were estimated to contain 254 000 tonnes of recoverable barite.

The Mineral King Mine area is underlain by three Proterozoic formations – Dutch Creek, Mount Nelson and Toby - that overlie an unnamed formation at the base of the section (Fyles, 1959a,c; Reesor, 1973; see Table 21). The Proterozoic sedimentary rocks lie stratigraphically near the top of the Helikian Purcell Supergroup and the base of the Hadrynian Windermere Supergroup. The strata have been subjected to intricate folding and extensive faulting and the dolomite of the Mount Nelson formation has been locally replaced by sulphide-barite mineralization near faults and near the contact with overlying argillite or slate horizons.

The structural setting is characterized by complex folds cut by many faults. The host dolomite in the region around the Mineral King Mine occurs in a syncline. Lenses of argillite in the dolomite and banding within some orebodies outline folds within the mine dolomite that plunge northwest at variable angles. Cross-warps have been identified in the upper part of the mine and several faults have been mapped.

The principal sulphides are sphalerite, galena, pyrite and minor bournonite in a gangue of dolomite, barite and quartz. In the upper part of the mine, sphalerite and galena occur either in irregular masses and lenses or in stratiform bands in the dolomite. The sulphides are most abundant around the margins of the barite bodies but are also irregularly distributed within the barite. Pyrite is either closely associated with galena and sphalerite or occurs in separate bands and lenses within, or marginal to, the orebodies. Bournonite, most conspicuous in the barite, is scattered irregularly through most of the ore into early pure barite zones between the "C" and "D" ore zones. The barite bodies range in size from one to several metres thick and one to two hundred metres long. They are irregular in shape and plunge northwest. Barite is white, fine- to medium-coarse-grained with a sugary texture. A few of the bodies were mined solely for their barite content.

Ore grades and lead-zinc ratios were extremely variable, with the former locally reaching 15% combined Pb-Zn. Mill-feed ranged from 5 to 10% combined Pb-Zn with the zinc commonly the most abundant. Minor copper was also recovered. Thompson and Panteleyev (1976) classify the Mineral King as a Salmo-type deposit, characterized by dolomite-sulphide bodies replacing limestone in complexly folded structures, whereas Sangster (1970, 1976) favours a syngenetic sedimentary origin.

Silver Giant Mine. The Silver Giant Mine (82-43), discovered in 1883 on the southwest side of Jubilee Mountain, west of Spillamacheen (Reesor, 1973), was a base metals producer until its closure in 1957. Baroid of Canada Limited purchased the property in 1960 to recover barite from the tailings and the abandoned mine.

The mine area is underlain by beds of Middle and Upper Cambrian Jubilee (Ottertail) Formation and the overlying beds of the Cambrian and Ordovician McKay Group. The former grades upwards from thinly bedded dolomite to more massive varieties. The latter has intraformational conglomerate at its base and shale and limestone at its top.

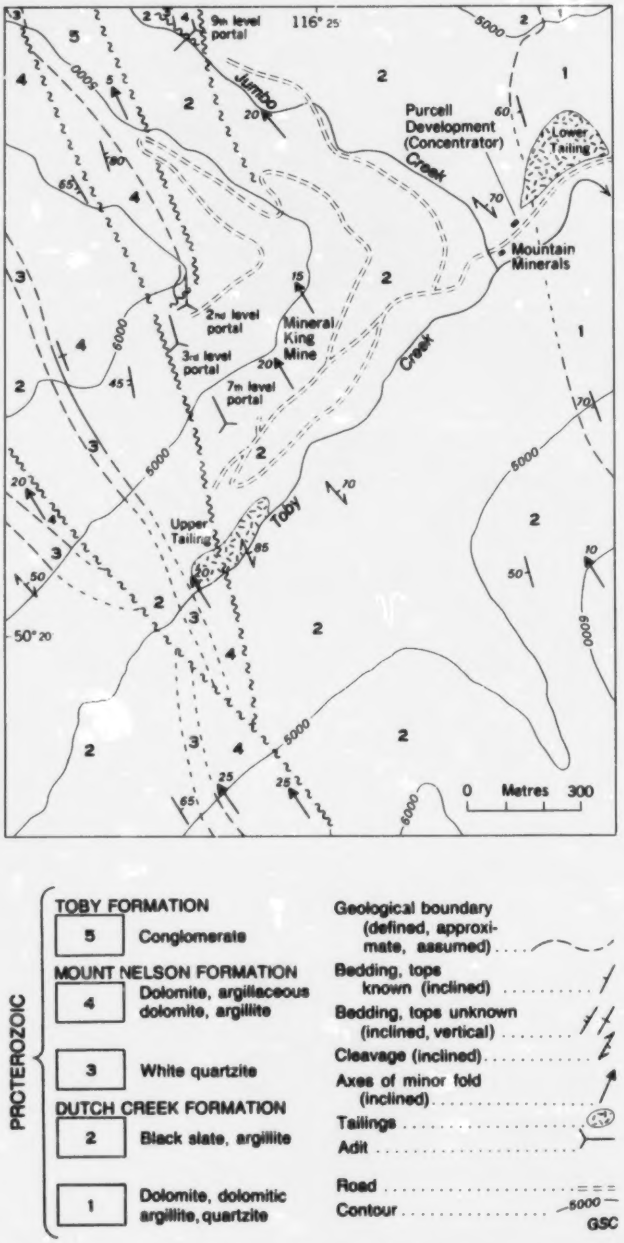

9th level portal
116° 25
Jumbo
Creek
Purcell Development (Concentrator)
Lower Tailing
Mountain Minerals
2nd level portal
3rd level portal
7th level portal
Mineral King Mine
Toby
Creek
Upper Tailing
50° 20
5000
6000
0 Metres 300
PROTEROZOIC
TOBY FORMATION
5 Conglomerate
MOUNT NELSON FORMATION
4 Dolomite, argillaceous dolomite, argillite
3 White quartzite
DUTCH CREEK FORMATION
2 Black slate, argillite
1 Dolomite, dolomitic argillite, quartzite
Geological boundary (defined, approximate, assumed)
Bedding, tops known (inclined)
Bedding, tops unknown (inclined, vertical)
Cleavage (inclined)
Axes of minor fold (inclined)
Tailings
Adit
Road
Contour
GSC

Figure 19. *Geology of the Mineral King mine, Invermere, British Columbia.*

Table 21. Table of Formations, Mineral King Mine area, Invermere, British Columbia

Era	Period or epoch	Formation	Lithology
Proterozoic	Windermere (Hadrynian)	Toby Formation	Polymict conglomerate with pebbles of various compositions; matrix impure limestone, shale and quartzite
		Unconformity	
	Purcell (Helikian)	Mount Nelson Formation	Buff and grey dolomite and dolomitic limestone, slate, argillite, white quartzite, dolomite and black slate
		Dutch Creek Formation	Varicoloured slate, quartzite, some argillite, dolomite, dolomitic argillite, black slate and argillite
		Kitchener-Siyeh Formation	Dark grey argillite, argillite and quartzite

Source: Fyles, 1959c; Reesor, 1973.

The mineralization occurs at the contact between the two formations. The orebodies occur on the crest of an overturned anticline that was subsequently folded and faulted.

The main sulphide orebody occurs in the nose of a local overturned anticline that strikes south 75° west and the angle of plunge (45°) decreases with depth. The structure has a limestone core sheathed with slate or argillite. A major thrust fault has been mapped 0.4 km west of the mine and in the underground workings. Several other faults encountered underground are believed to be normal faults that dip mainly southwest and have displaced the local stratigraphy. They contribute to the structural complexity of the deposit and suggest that there was more than one period of deformation.

The orebodies, which are sulphide-barite replacements with variable amounts of silica, are located beneath the slate at its contact with the limestone. They lie at the nose of the fold, along one of its limbs, and at intervals elsewhere along the slate-limestone contact. The overlying slate is locally brecciated and black silicified clasts have been identified in the sulphide-barite replacement bodies. A few barite replacement zones occur in the limestone away from the contact but these are usually lacking in sulphides. They probably represent the roots of eroded orebodies because the structural rake exceeds the slope of the mountain side in this area.

The mineralogy of the ore in the sulphide-bearing barite and barite-silicate replacement bodies is simple. The sulphides consist mainly of fine-grained galena that has a low silver content, a lesser amount of sphalerite and pyrite, minor chalcopyrite and bornite and trace amounts of tetrahedrite and tennantite. The barite is commonly white and varies from very fine grained to coarse bladed crystal aggregates. The fine grained barite may be either massive or foliated and commonly carries streaks of sulphides or argillaceous material.

Atlantic Provinces

Southeastern New Brunswick, northern Nova Scotia and southern Prince Edward island have a few replacement barite occurrences in a variety of clastic sedimentary rocks. Carboniferous red or grey sandstone and conglomerate contain barite occurrences at St. Mary's Point (21-28), New Brunswick and Gibbons Point, Nova Scotia (Sabina, 1965). Here barite has replaced carbonaceous plant fossils but both sites have only mineralogical significance. It is probable that the barium was scavenged from the host sediment and was deposited in an anaerobic or reducing environment associated with amorphous carbon or coalified plant fossils. The limited variety of metallic sulphides and the absence of major faults or nearby igneous intrusions make it unlikely that the barite depositing solutions were hydrothermal or telethermal in origin. The Gallas Point (11-45) occurrence, Prince Edward Island is also contained in Carboniferous sandstone and here barite is associated with plant and tree fossils as well as partly filling worm burrows (Sabina, 1965). The barite is associated with hematite, fine-grained crystalline quartz, calcite and fine-grained pyrite. As in the case with the St. Mary's Point (21-28) and Gibbons Point occurrences, the barium is probably derived from nearby sedimentary rocks.

Walton Mine. The Walton Mine (21-13) is located 3.3 km southwest of Walton, Nova Scotia (Boyle, 1972; Campbell, 1942; Fig. 20). Barite was recognized in a small outcrop of impure barite breccia many years before commercial development began. An intensive drilling program in the fall and winter of 1940-41 outlined the large barite orebody that was in production until 1978. In 1956, a second drilling program outlined a lead-zinc-copper-silver orebody beneath the barite which was promptly brought into production.

The geology of the mine area is dominated by Carboniferous sedimentary rock (Bell, 1929, 1960). The oldest rocks are the Mississippian Horton and Windsor groups. The Horton Group has been subdivided into fluviatile and lacustrine formations, the Horton Bluff and Cheverie, respectively. The Cheverie is conformably overlain by rocks of the Windsor Group that include, from base to top, the Macumber, Pembroke, Evaporite, and Tennycape formations as well as an undivided unit. The Windsor beds are separated from the overlying Triassic red sandstone, conglomerate and shale by a marked unconformity (Bell, 1929, 1960). Triassic gabbro sills intrude the Horton bluff sedimentary rocks at Johnson Cove but they are not known in the vicinity of the mine.

The structural geology in the vicinity of the Walton Mine is complex and full details are not known. The sedimentary section is cut by a major east-west fault zone with an approximate dip 70° to the north. This fault lies in the footwall of the barite body and is joined by another that strikes approximately northwest on the hanging wall of the orebody. Both faults, particularly the footwall fault, are characterized by a breccia zone several metres thick. The faults are pre-ore but there are also a few post-ore faults, as shown by the occurrence of brecciated barite and sulphide ore. The pre-ore faults brecciated and contorted rocks of the Evaporite, Macumber, Pembroke formations and the upper part of the Cheverie Formation. The localization of both the barite and sulphide bodies is thought to be related to the structural complexities, the dilatant breccia zones, bed porosity and the proximity of the Horton-Windsor contact.

Two orebodies occur in the Walton Mine – a large barite pipe and a massive sulphide lens. The former was exposed on the surface and the latter was discovered at a depth of 75 m as a result of geochemical sampling in the barite open pit (Boyle, 1972). The barite orebody was pear-shaped in surface plan and pipe-like in vertical section with a 35° east rake. The lens-shaped sulphide orebody was found in the footwall of the barite body where the footwall curves from east to a more southerly trend. The barite was probably localized by the east raking (35°) intersection of two major pre-ore faults. The ore was brecciated and recemented by red mud near the hanging wall.

The minerals in the sulphide body include galena, sphalerite, pyrite, marcasite, tennantite, proustite, chalcopyrite, bornite, argentite, gersdorffite, barite (25%), hematite, siderite, dolomite, calcite and chlorite. The supergene minerals include pyrolusite, psilomelane, manganite, secondary hematite, secondary barite, limonite, chalcocite, malachite, azurite, calcite and unidentified nickel and cobalt minerals. The barite ore ranges from nearly pure barite to mixtures in which hematite, dolomite, siderite, pyrolusite and psilomelane are identified. Assays indicate that strontium in this ore has probably substituted for Ba in barite. Both the siderite and dolomite are manganiferous and are a probable source of some of the secondary manganese oxides. Most of the hematite is very fine grained, pulverulent and ocherous and was derived in part from the Tennycape red siltstone and the Pembroke red limestone. Much of the barite is fine grained with a saccharoidal texture and is only rarely coarse grained. It varies in colour from white to pink, to red and mottled, or banded greyish to black. The red colour is due to fine grained hematite and the grey and black colours to amorphous carbon or bitumen.

In terms of paragenesis the hypogene mineralization has been subdivided into three main stages: (1) the deposition of carbonates with minor quartz and pyrite in small-scale dilatant openings in the Carboniferous rocks; (2) the main deposition of barite, carbonates and metallic sulphides under reducing conditions at depth and under oxidizing conditions near surface and, finally; (3) minor deposition of calcite and barite near the orebody and pyrite, chalcopyrite, galena and barite with carbonaceous plant remains in the surrounding Cheverie Formation (Boyle, 1972). This was followed by supergene oxidation near the surface, a process still operative today. It is probable that the manganese oxides, barite, siderite and sulphides were deposited from chloride brines that pervaded the Horton and Windsor rocks. As the brines entered favourable structural and chemical sites they precipitated barite, siderite and sulphides. Manganese oxides, calcite and minor barite were precipitated in near-surface zones that had higher oxidation potential. Erosion of the surface initiated the supergene environment and produced the appropriate minerals. It is probable that the ore-forming elements were derived from the rocks of the Horton Group. That much of the barite mineralization preceded the sulphide deposition is demonstrated by the fact the footwall breccia zone of the barite body has been recemented by galena, sphalerite and tennantite. The presence of barite in the sulphide body indicates the spatial and chronological overlap of the non-metallic and metallic phases of deposition.

Unclassified Deposits

Many deposits and occurrences have not been classified in this study. This is the case if the source document does not identify the kind of deposit or if there is insufficient evidence to permit unambiguous classification. Unclassified deposits occur in the Yukon Territory, British Columbia and Ontario.

Yukon Territory

Two occurrences of barium minerals in contact aureoles adjoining felsic stocks have been described from Yukon Territory. They are the Clyde Smith (105-20) and Wilson Lake (105-17) occurrences in the Macmillan Pass area of eastern Yukon Territory, and both have little apparent economic promise. The former is reported to be a barite vein cutting a skarn zone in the aureole of a quartz monzonite (K.M. Dawson, oral communication, 1976). The Wilson Lake occurrence is also near a granodiorite stock and its contact with a sequence of metasedimentary rocks derived from argillite, orthoquartzite and limestone (Montgomery, 1960). Barium silicates occur in skarn lenses in the metasedimentary rocks. The minerals reported include hedenbergite, gillespite, keeleyite ($Pb_6Sb_{14}S_{27}$), taramellite (Table 10) and minor sulphides (Montgomery et al., 1972).

British Columbia

British Columbia occurrences include the Homestake Mine (82-45); Highland Light (82-26); Larrabee (82-37); Highlander (Highland Mine) (82-17) and Galena Farm (Currie Group) (82-27). With one exception the main production from these deposits was silver or lead but the ores contained barite as a gangue constituent. Baroid of Canada Limited mined 72 tonnes of barite from the Larrabee property between 1959 and 1960 from mineralization in several fault-controlled lenses that cut across a sericitic phyllite of the Helikian Mount Nelson Formation.

Homestake Mine

The Homestake Mine (82-45) (Fig. 21) lies about 48 km northeast of Kamloops. The property is underlain mainly by Adams Lake Series quartz-sericite-talc and quartz-chlorite-talc schists (Campbell, 1961; Campbell and Okulitch, 1976; Segonich, 1973). The schists are locally nodular and contain veins of pyrite as well as disseminated pyrite crystals. The nodular beds have been interpreted as sheared conglomerate and the chloritic phase near the top of the section was derived from sheared volcanic rocks. There are also discontinuous conformable lenses of phyllite in the section. The beds strike north 40° west and dip from 30° to 40° north. The schist section is about 700 m thick near the mine. A major northeast striking sinistral fault underlies Falls Creek and displaces the orebodies to the southwest. Other faults have been identified underground but none have displaced the orebodies in the mine.

Three principal orebodies have been described: the footwall or barite vein; the hanging wall lead or the schistose zone; and the main 300 vein. The footwall or barite vein is a stratabound body consisting of one to three subveins in sericite schist. Individually they are tabular bodies 0.3 to 10 m thick by 70 m long, containing massive, fine grained barite and minor sulphides locally characterized by alternating grey and black bands separated by schist partings. Some sulphide bands that carry tetrahedrite, galena, sphalerite, argentite and native silver are also present. The sulphides rarely comprise more than one per cent of the footwall vein.

The hanging wall lead lies 5 m stratigraphically above the footwall vein and is also stratabound. It consists of alternating bands of schist, barite and sulphides cut by thin

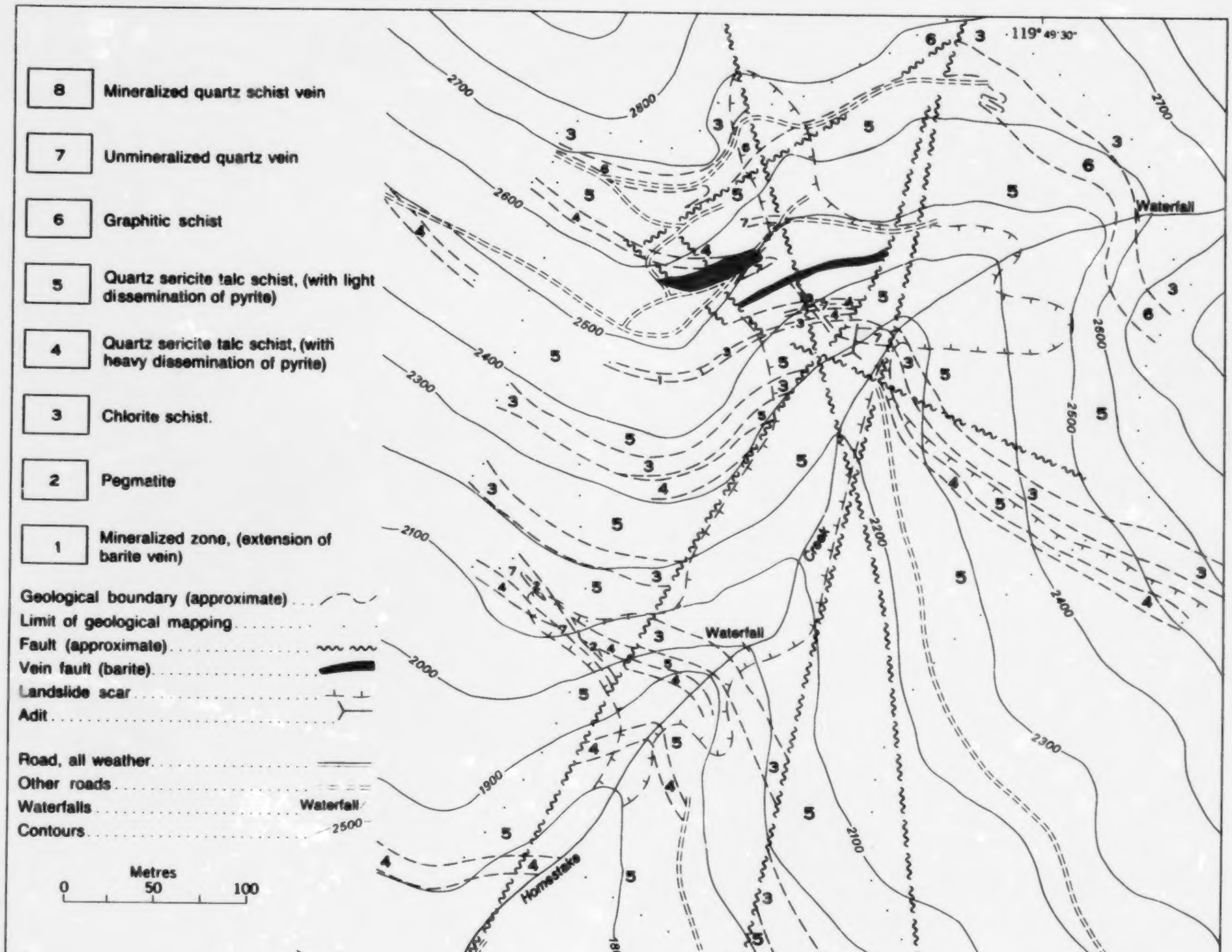

8 Mineralized quartz schist vein
7 Unmineralized quartz vein
6 Graphitic schist
5 Quartz sericite talc schist, (with light dissemination of pyrite)
4 Quartz sericite talc schist, (with heavy dissemination of pyrite)
3 Chlorite schist.
2 Pegmatite
1 Mineralized zone, (extension of barite vein)
Geological boundary (approximate)
Limit of geological mapping
Fault (approximate)
Vein fault (barite)
Landslide scar
Adit
Road, all weather
Other roads
Waterfalls
Waterfall
Contours
2500
Metres
0
50
100
119° 49' 30"
51° 05' 25"
Waterfall
Creek
Homestake
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
Core Shack
Old Mill
SQUAM BAY ROAD
OLD TAILINGS POND
Abandoned school house
GSC

Figure 21. *Geology of the Homestake Mine, Adams Lake, British Columbia.*

quartz lenses that contain argentite films on fractured quartz grains. The hanging wall lead forms the main orebody and it contains a wide variety of metallic minerals including tetrahedrite, galena, sphalerite, chalcopyrite, argentite, native silver, ruby silver and native gold.

The main 300 vein lies 42 m stratigraphically above the others and consists of a zone of barite and disseminated sulphides 1.3 to 8.3 m wide. The mineralization is similar to that of the other two zones and is believed to be the continuation of a vein exposed at the surface. The lower contact of the zone is marked by a minor fault and the upper contact parallels the schistosity of the enclosing host rocks.

The schists contain other barite bands and barren quartz lenses that offer little prospect for suphide production. A few thousand tonnes of sulphide concentrate have been mined from the main veins over the years but known reserves of sulphides and barite ore are not large (1 004 029 tonnes, 198.5 kg/tonne Ag, 2.5% Pb, 4.0% Zn, 0.55% Cu, 28% Barite; NMI CARD,[1] 1977. Some geologists believe the Homestake orebodies to be volcanogenic massive sulphide deposits which have been metamorphosed and deformed (K.M. Dawson, oral communication, 1981). The author, lacking convincing evidence, prefers to leave the Homestake Deposit unclassified.

Ontario

Three barite occurrences in Ontario have not been classified because of the lack of data. These include: Clyde Forks (31-85), North Burgess (31-65) and Ramsay (31-86) (Fig. 22).

Clyde Forks Property

More extensively developed that the other two, this property is 3.2 km west of the village of Clyde Forks (31-85), Lanark County (Nikols, 1972). Here, clean white barite occurs in Proterozoic marble in a zone 152 cm wide that has been traced 91 m along strike and 150 m down dip. The zone conforms to the enclosing marble beds which form symmetrical cylindrical folds that trend N 55° E. The barite zone may represent a barite bed in the marble. The axial surfaces dip 40° SE. The folds are weakly developed on a regional northeast dipping homoclinal structure. The zone does not coincide with nearby N 55° E striking faults.

The Clyde Forks barite is hard, crystalline, medium- to coarse-grained, semi-translucent and white to bluish- or greyish-white. It is associated with a variety of minerals including: mercurian tetrahedrite, stibnite, chalcopyrite, arsenopyrite, chalcostibite, getchellite, cinnabar and pyrite in conformable nodular segregations and disseminations along relict bedding planes in the Proterozoic marble. The overlying marble is enriched in Sb, Cu, Ag and Mn. The main gangue minerals are coarse grained calcite and minor amounts of disseminated quartz. The secondary minerals present include cinnabar, malachite and azurite.

Strontium

Records of Canadian strontium deposits and occurrences in the computer data file are far fewer than those for barium and fluorine, probably because the small demand for strontium has not encouraged the same amount of prospecting and mine development. The element occurs among the first four elements in 37 of the 733 records in the data bank. The most common element, ore mineral, gangue mineral, wall rock and wall rock age for the 37 celestite deposits are listed in Table 22.

Table 22. Characteristics of Sr-bearing deposits in Canada

Most abundant element	No. of occurrences/deposits	Wall rocks	No. of occurrences/deposits
Sr	24	limestone	15
Ba	4	marble	6
F	4	dolomite	3
Nb, Au, Zr, U, Ca	1 each	carbonatite	2
		syenite, sandstone, shale	2 each
		feldspar porphyry, granite, greenstone, pegmatite, slate	1 each
Ore Minerals		Wall rock ages	
celestite	21	Cenozoic	
strontianite	3	Quaternary	1
fluorite	4	Paleozoic	25
barite	3	Permian	1
gold	2	Carboniferous	8
pyrochlore, weloganite, uraninite, gypsum	1 each	Mississippian	2
		Ordovician	6
		Devonian	4
		Silurian	1
		Proterozoic	1
		Archean	3
Gangue minerals			
calcite	14		
apatite, columbite, quartz, microcline, gypsum, fluorite	1 each		

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[1] **NMI CARD, record from Mineral Policy Sector, Department of Energy, Mines, and Resources. NMI = National Mineral Inventory.**

Syngenetic Deposits

The strontium deposits classified here as syngenetic are discussed with examples under two main classes (see Table 23); those formed in igneous intrusive rocks and those formed in sedimentary rocks. Neither class has been a source of celestite in Canada although production is obtained from eluvial sediments at Yate, England and is associated with playa evaporite deposits at Bristol Dry Lake, California.

Igneous Intrusive Rocks

Salic Rocks

Strontianite has been reported as fibers and small sheets in the west part of the Ben Loyal syenite intrusions, in western Scotland (Thomas, 1973). No Canadian representative of this type of occurrence is known.

Felsic Rocks

Celestite occurs rarely in felsic intrusive rocks. One such occurrence has been reported in Scotland where small, irregular celestite plates are present in microadamellite dykes cutting the main plutonic complex at Glenelg-Ratagan (Western Highland, Sound of Sleat, Scotland; Thomas, 1973). It also occurs as a fine grained interstitial constituent of a sheared feldspathic rock at the Rexspar Mine (82-50), Birch Island, British Columbia. The sheared feldspathic rock may be a metamorphosed pyroclastic flow, a feldspar porphyry dyke, or arkose, and consequently the author prefers to leave the Rexspar deposit unclassified. Here, celestite is associated with fluorite but the mineralogical complexity of this occurrence renders economic separation of celestite difficult.

Carbonatite Complexes

Celestite has been reported in the carbonatite complex at Oka, Québec in a syngenetic association. However, it is not a potential economic source of the element (Rowe, 1958).

Table 23. Classification of syngenetic strontium deposits

Class	Examples
Alkaline rocks	Ben Loyal syenite, Scotland
Felsic rocks	Rexspar (Birch Island) (82-51), B.C.; Glenelg-Ratagan, Scotland.
Carbonatite complexes	St. Lawrence Columbium mine (31-98), Que.
Clastic sediments	
Eluvial deposits	Yate, U.K.
Chemical sediments	
Evaporites	Persian Gulf sabkha deposit.
Carbonates	Cape Robert (41-02), Manitouwaning (41-01) and Frazer Duntile quarry (31-93), Ont.; Bass Island Dolomite, Illinois, U.S.A.
Biochemical sediments	
Carbonates	
Brines	Brines in U.K.; Great Salt Lake, Utah; Bristol Dry Lake, California, U.S.A.

Sedimentary Rocks

Clastic Sediments

Celestite occurs only rarely in economic amounts in residual soils.

Yate Deposits. A few thousand tons per year were recovered from the residual soil and the underlying weakly consolidated Keuper Marl and Lower Coal Measure beds near Yate, Bristol area, England (Thomas, 1973; Nickless et al., 1976) (Fig. 23, Table 24). Celestite was mined for 100 years in this area and the operation supplied 50 to 70 per cent of world production between 1875 and 1968. The Keuper Marl contains celestite in more than one horizon but only that associated with the Severnside Evaporite, 10 to 15 m beneath the Tea Green Marl is important (see Table 24). Three types of ore are recognized. Type A contains celestite in nodular and disseminated forms as well as in thin stringers and veins in the Severnside Evaporite bed of the Keuper Marl. Type B comprises nodular and disseminated celestite contemporaneous with the Severnside evaporite bed–that occurs at the unconformity between the Keuper Marl and the underlying Palaeozoic Coal Measures. Type C consists of veins, sheets and vug fillings of remobilized celestite in the Keuper Marl and the underlying Palaeozoic rocks.

Celestite is also reported in a similar type of deposit in the Purbeck Formation at Durlston Head, Dorset, England. This residual deposit is interpreted as a product of weathering of celestite-rich gypsum and anhydrite beds (Thomas, 1973).

Chemical Sediments

Evaporites. Fossil and modern evaporite deposits contain anomalous amounts of strontium. Crystalline celestite was reported as one of the early diagenetic minerals growing in the sabkha environment of Abu Dhabi, Persia (Evans and Shearman, 1964; Evans et al., 1969; Butler, 1973). Single euhedral crystals of celestite and very fine grained aggregates in a variety of forms have been described

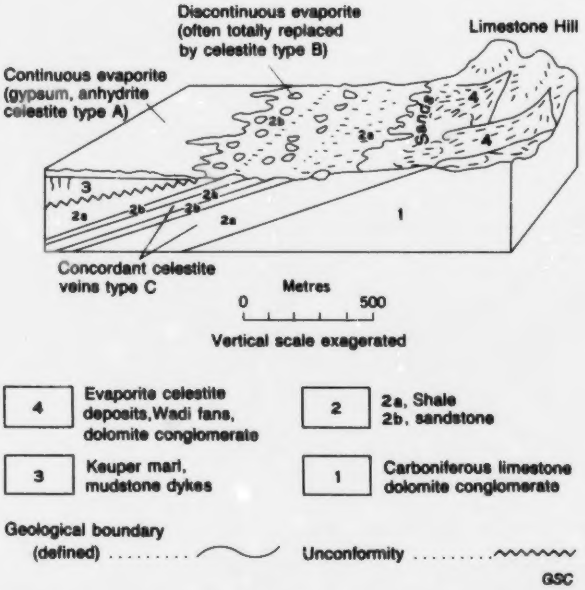

Discontinuous evaporite
(often totally replaced
by celestite type B)
Limestone Hill
Continuous evaporite
(gypsum, anhydrite
celestite type A)
2b
2a
Sand
4
4
3
2a
2b
2b
2b
2a
1
Concordant celestite
veins type C
Metres
0
500
Vertical scale exagerated
4
Evaporite celestite
deposits,Wadi fans,
dolomite conglomerate
2
2a, Shale
2b, sandstone
3
Keuper marl,
mudstone dykes
1
Carboniferous limestone
dolomite conglomerate
Geological boundary
(defined)
Unconformity
GSC

Figure 23. *Block diagram illustrating the three modes of celestite occurrence, Yate, England.*

Table 24. Partial table of formations for the Yate, England celestite mining area

Era	Period or epoch	Formation Names	Lithology
Mesozoic	Jurassic Lias	White and blue Lias	Clays and limestones
	Triassic	Cotham Beds	Greenish grey silts, muds, splintery calcitic mudstone
	Rhaetic	Westbury beds	Black shales
	Keuper	Tea Green Marl	Calcareous greenish grey clays and mudstones
		Keuper Marl	Silty calcareous red mudstone
		Major unconformity	
Paleozoic	Carboniferous	Upper Coal Measures Supra-Pennant Measures Pennant Measures Lower and Middle Coal Measures Millstone Grit	Interbedded shale and coal Sandstones Limestones

Source: Nickless et al., 1976

from the sabkha environment. Some aggregates resemble spherulites. Simple clusters may represent an early stage of development of sheaves although the progression from one form to the other has not been documented. The mineral is commonly associated with gypsum which also exhibits a variety of crystal habits. The two minerals occur together less than 1 m below the surface and beneath the algal mat for several kilometres inland from the sea. Strontium must have precipitated originally from the seawater-derived brine but much of it probably crystallized at a later stage during the dolomitization of strontium-bearing aragonite.

Celestite has been recovered from on or near the surface of lake muds at the south side of Bristol Dry Lake, California (Gale, 1951). It occurs in nodular lumps several centimetres across consisting of white microcrystalline aggregates elongated parallel to bedding. A similar type of celestite deposit is reported in Death Valley, California. There is little exploitation of deposits of this type because they are too low grade.

Carbonate rocks. Primary celestite is reported as disseminated crystals and circular spots in typical fine-grained carbonates at several localities in Ontario; Cape Robert (41-02), Manitouwaning (41-01) and Frazer-Duntile Quarry (31-93). These represent shelf or shallow water carbonates interbedded with evaporites in the same stratigraphic section. For example the Silurian Bass Island dolomite that outcrops in New York, Illinois and Michigan is characterized by both disseminated celestite crystals and round aggregates of crystals. The dolomite is a member of an evaporite sequence that includes salt and anhydrite beds and is devoid of fossils. In this case, the strontium precipitated from a marine brine into lime muds (Graf, 1960).

Biochemical Sediments

Modern carbonate-secreting marine organisms have been analyzed for their strontium content. The aragonite-bearing skeletons of recent clams and snails accumulate up to four per cent strontium from seawater. The strontium enrichment of snail shells is more closely related to the snail genus than to the calcite-aragonite ratio displayed by their shells. Certain **Nudibranchia** (marine gastropods) and **Madreporaria** (reef building corals) also secrete strontium-rich skeletons (Graf, 1960). Organisms having a low calcite-aragonite ratio can accumulate more strontium because the aragonite molecule has a greater capacity to do so than calcite. Subsequent replacement of the aragonite by calcite frees the strontium to combine with available sulphate and crystallize as celestite. Species that produce aragonite include pelecypods, gastropods, calcitic algae and decapods. Strontium–calcium ratios that have not been changed diagenetically can be used to distinguish between fresh and salt water species (Odum, 1957). One modern celestite-secreting radiolaria, **Actiplea,** has been reported. Biochemical processes are responsible for some of the celestite occurrences reported in limestones and dolomites. None are large enough to have commercial significance but such biochemical accumulations may have been a source of the element for epigenetic veins subsequently formed elsewhere.

Surface waters, ground waters and brines

Strontium is more widespread in brines than either barium or fluorine. Anomalous amounts of strontium have been reported in brines from North America and Great Britain. Brines in Great Salt Lake, Utah contain 2.1 mg/l strontium and those of Bristol Dry Lake, California contain up to 962 mg/l of strontium. As noted previously, celesite has been recovered from on or near the surface of lake muds of Bristol Dry Lake (Gale, 1951), and a similar occurrence has been reported in Death Valley, California. These are of little economic interest because they are too low in grade. Strontium-rich brines may, however, have been the primary source of the replacement deposits mined at Kaiser Celestite Mine (11-28) (Fig. 24), Nova Scotia and for the Ronan (12-05) and Gillams Cove (12-07), occurrences on Port au Port Peninsula, Newfoundland.

Thermal springs in Derbyshire, England contain 1 mg/l of strontium and Coal Measure brines in Northumberland and Durham contain anomalous amounts of the element. It is also reported in water pumped at Frampton-Cottrell pumping station, Gloucestershire, England.

Epigenetic Deposits

Epigenetic strontium deposits – of which 26 are known in Canada – are characterized by celestite or strontianite in fissure-fillings or replacement bodies (Table 25). They are more widespread and economically more important that the syngenetic strontium deposits. Canada's major production was limited to the period 1969-1976. This was obtained from replacement bodies in Carboniferous limestones in Nova Scotia. A few deposits are unclassified owing to uncertainty regarding their genesis.

Fissure Fillings

Celestite occurs in fissure fillings in Ontario, Québec, New Brunswick and Nova Scotia. Celestite was reported filling vugs in gold-quartz veins that cut syenite in the old Lake Shore Gold Mine (42-04) (Hawley, 1948). The mineral also occurs in lead veins in the abandoned Frontenac Lead Mine (31-09) and the Perry Fluorite Mine (31-16, -17) in southern Ontario. Strontianite is reported in veins in parts of the Oka carbonatite complex (31-98) along with barite (Rowe, 1958). The mineral also occupies fissures in chemical sediments on the Dorchester (Dorbeck) (21-31), New Brunswick property. Celestite occurs in fissure fillings at Cheverie Cliffs (21-09) and Corney Brook (Cap Rouge) (11-59) in Nova Scotia. The mineral is mined from veins in carbonate rocks at Matehuaha and Torreón-Saltillo, Mexico (Industrial Minerals, 1974).

Replacement Deposits

Kaiser Celestite Mine

The best Canadian example of this type of deposit is the Kaiser Celestite mine (11-28) from which most of Canada's past production of strontium has come. The Kaiser Celestite Mine (11-28) (Fig. 24) is located 51 km southwest of Sydney, Nova Scotia (Crowell, 1971). The occurrence was found in 1962 by A.V. Hudgins who discovered celestite-bearing float and outcrops in the vicinity. Preliminary diamond drilling outlined a large lens of low grade celestite but market conditions did not encourage further work until 1969 when Kaiser Minerals acquired the property and undertook a major drilling program. An economic flotation procedure was developed by the CANMET branch of the Department of Energy, Mines and Resources, Ottawa in 1970 and based on this method production commenced the following year.

Because of the thick, widespread glacial till the bedrock geology of the mine site must be interpreted from float boulders, limited natural exposures, mine workings and diamond drill cores. The stratigraphic column was interpreted by Binney (1975) from cores from numerous drillholes located by a surveyed grid (Fig. 24). The sequence of events began with a period of block faulting in Devonian and Lower Carboniferous time that resulted in graben and horst structures. The former were partly filled by coarse clastic detritus eroded from the intervening horsts and deposited under continental conditions as a series of thick, coarse-clastic redbeds called the Lower Conglomerate (Grantmire Formation of the Windsor Group). This was followed by a marine transgression over the redbeds, characterized by the deposition of a grey, sandy, carbonaceous limestone (Lower or Basal Limestone). Finally a prograding clastic wedge (Red Bed sequence – Enon Formation) was formed, with intratidal stromatolites and supratidal evaporites covered by the upper conglomerate, upper limestone and the Loch Lomond Evaporites. The basement rocks underlying the mine are (Devonian) igneous intrusive rocks of intermediate composition.

Table 25. Classification of epigenetic strontium deposits

Classes	Examples
Fissure Fillings	Lake Shore Gold Mine (42-04), Frontenac Lead Mine (31-9), Perry Mine (31-17), Ont.; Oka (31-98), Qué.; Dorchester (Dorbeck) (21-31), N.B.; Cheverie Cliffs (21-9) and Corney Brook (Cap Rouge) (11-59), N.S.; and Matehuaha and Torreon-Saltillo, Mexico.
Replacement Deposits	Kaiser Celestite (11-28), N.S.; Gillams Cove (12-6, 7), Nfld.
Unclassified Deposits	Rexspar (Birch Island) (82-51), B.C.; Wilder (31-89), Ont.

Structurally the area is characterized by pre-ore block faulting and sedimentary deposition on an irregular pre-Carboniferous surface. The orebodies are localized along identifiable basement topographic highs. Other faults are suspected in the area but are not clearly defined. The sedimentary rocks have not been noticeably folded but lie much as originally deposited with dips of eight to ten degrees northwest.

The celestite ore occurs in five different forms: (1) beds and void fillings; less commonly; (2) replacements of fossils; (3) calcite-celestite veins; (4) disseminated grains and, (5) aggregates of grains in gypsum beds (Choo, 1972). The celestite beds are variable in thickness, terminate abruptly and recommence again at approximately the same stratigraphic level. Thin beds four to five mm thick alternating with iron-stained celestite and grey limestone are locally preserved. The high grade ores occur in massive beds having from 85 to 95 per cent celestite associated with two to three per cent iron oxides and four to five per cent combined calcite and dolomite. Silt-sized quartz grains have also been identified as a minor constituent of the massive celestite.

Celestite beds range from iron-poor to iron-rich. The iron-rich celestite beds contain 40 to 50 per cent iron oxide minerals, 40 to 50 per cent celestite, 5 to 7 per cent calcite, 2 to 3 per cent silt-size quartz grains and trace amounts of dolomite and sepiolite. Euhedral and subhedral celestite crystals are isolated in the iron cement whereas the anhedral celestite forms interlocking aggregates. Individual celestite crystals are lath shaped, 0.3 to 0.5 mm by 0.1 to 0.15 mm, and oriented subparallel to the bedding planes. Minor amounts of quartz and calcite occur as inclusions in celestite crystals.

The iron-poor celestite beds rarely contain more than 15% celestite. Elsewhere, celestite, calcite and dolomite combine to fill solution cavities and vugs in limestone, silty limestone, calcareous limestone and conglomerate members in both the basal and middle limestone units. Trace amounts of aragonite and strontianite have been identified in a few of the vugs and some celestite crystals contain inclusions of either calcite or dolomite.

Celestite rarely occurs as partial replacements of calcite- or aragonite-rich fossils, in calcite veins and disseminated within gypsum beds. Veins occur in several of the sedimentary and underlying basement rocks. Some veins grade up to 85 per cent celestite with varying amounts of calcite and iron minerals. Celestite is a minor constituent of some gypsum beds along with magnesite, hematite, amorphous carbon, pyrite and barite. It occurs as isolated grains, patches and nodules, having no commercial importance.

The ore occurs in five horizons at the Kaiser celestite mine (Fig. 24). One manto is hosted by the Enon Formation gypsum member, two by the Loch Lomond Formation limestone, one by the Loch Lomond Formation gypsum and one by the Uist Formation siltstone. All occur on flanks of basement highs, relicts of the intergraben horsts produced by early block faulting. The orebodies hosted by the siltstone show rapid facies change to gypsum and barren siltstone and those in the limestone grade laterally into gypsiferous dolomite or barren limestone. The host limestone is characterized by rapid facies changes from highly fossiliferous reef and bank forms on the flanks of the basement highs to calcarenites without mega-fossils, short distances from the highs. Bed thickness ranges from 4.5 to 21 m.

Economic bodies of celestite are restricted to the east side of the Loch Lomond basin and barite is reported from the western side. The celestite grade changes laterally from low at the orebody – basement interface to a peak value away from the interface and then declines abruptly into barren gypsum. The textural appearance of the celestite in the siltstone or limestone is almost identical to that of gypsum in the same surroundings. Few drillholes have penetrated the transition zone between celestite ore and barren gypsum.

The origin of the celestite is still a matter of debate but three genetic models have been proposed: (1) replacement of limestone or siltstone along the east margin of Loch Lomond basin by hydrothermal or telethermal solutions that originated at the centre of the basin; (2) coprecipitation of celestite and gypsum during early diagenesis as void fillings, and fossil shell fillings and displacement nodules in the host rocks; and, (3) replacements of gypsum during late diagenesis. The last is favoured by Crowell (1971). It is probable that the celestite and gypsum precipitated contemporaneously in a supratidal environment during early diagenesis. Both were probably ultimately derived from weathering of the basement rocks, transported in a sabkha or playa lake environment and there concentrated by brine development as normal evaporite products, particularly in the shallows flanking basement highs.

Port au Port Deposits

In eastern Port au Port Peninsula, Newfoundland a few small occurrences of celestite have been reported near the villages of Boswarlos and Aguathuna (McArthur, 1973, 1974; Carr, 1954, 1958; Johnson, 1954; Riley, 1962). All are accessible by highway and are about 25 km west of Stephenville, Newfoundland. Two deposits - Gillams Cove (12-06, -07) and Ronan (Hoopers Brook 12-05) – have been trenched and drilled and reserve estimates have been published.

The Gillams Cove deposit occurs 0.8 km west of Aguathuna at the north end of a small valley. The mineralization occurs in a bench 12 m high, 45 m wide and 600 m long on the east side of the valley. The bench is an inlier of Upper Mississippian Codroy limestone that partly fills a pre-Carboniferous valley surrounded by barren Lower Ordovician Table Head limestone. The Codroy limestone is buff to brown, sandy to shaly limestone visible in float boulders and in outcrop at the base of the Table Head Limestone along the west side of the valley. The celestite is restricted to the Codroy limestone.

Table 26. Characteristics of fluorine-bearing deposits in Canada

Most abundant element (297)		Dominant ore mineral (216)	
F	297	Fluorite	216
Ba	38	Barite	37
Ag	19	Sphalerite, molybdenite,	
Pb	15	Chalcopyrite, argentite	5-10 each
Zn	7		
U	6		
Cu	6	**Dominant gangue minerals (261)**	
Au	6		
W, Nb, Li, Sn, Be,		Calcite	109
Fe, P	1-4 each	Quartz	86
		Pyrite	6
		Barite	4
		Others(157)[1]	1-3 each

Wall rock lithology (321)		Wall rock age (147)	
limestone	38	Cenozoic	
marble	20	Quaternary	5
shale	15	Mesozoic	
gneiss	13	Cretaceous	10
pegmatite	13	Jurassic	< 5
iron formation	12	Triassic	< 5
diabase	10		
syenite	9	Paleozoic	
skarn	8	Mississippian	9
rhyolite, tuff,		Devonian	66
slate	7 each	Silurian	9
sandstone	5	Ordovician	28
others(164)[1]	1-4 each		

[1] These represent the number of gangue minerals or wall rocks that occur less than four and five times respectively.

Crystalline celestite masses are concentrated in a zone parallel to the bedding that dips shallowly to the north. The ore consists of irregular boulders of Codroy limestone more or less completely cemented by crystalline celestite (60 to 65 per cent) and 35 to 40 per cent combined barite, calcite and aragonite. The mineralized body is 15 m thick, 45 m wide and 75 m long and contains estimated reserves of 17 678 tonnes of celestite-barite ore (McArthur, 1973).

The Ronan (Hoopers brook) (12-05) deposit occurs at Boswarlos, 0.8 km southwest of the mouth of Hoopers Brook. An outlier of Carboniferous Codroy limestone occurs along the brook in a Pre-Carboniferous valley cut into the underlying Table Head limestone. The deposit terminates to the south against a low escarpment of the Table Head limestone. A swampy, rolling, drift-covered lowland slopes from this point to the shore. It is underlain by 15 m of gently warped basal conglomerate, sand and shaly limestone and gypsum-bearing shales of the Codroy Group. The beds of the group lie disconformably on the Table Head limestone.

The Ronan body is wedge shaped and thickens north from the scarp towards the bay. It is bounded on the west by Table Head limestone and fingers out towards the east into the Codroy limestone. The lens is generally conformable with bedding in the Codroy limestone. A drill program outlined a mineralized zone 75 m wide, 105 m long and varying in thickness from 0.3 m at the south end to 12 m at the north end. Reserves of 152 400 tonnes of celestite-barite ore were calculated. Barite is more abundant here than at Gillams Cove (McArthur, 1973).

The mineralogy of the Port au Port ore is variable both within individual zones and between ore zones. Ore types include: (1) intergrowth of blue granular and white platy celestite in a massive, fine grained aggregate of celestite and aragonite; (2) friable, coarsely crystalline blue celestite in brecciated Codroy limestone; (3) large rounded nodules or crystal masses of celestite in sharp contact with sugary white or pinkish barite; (4) intergrowths of fine grained crystalline celestite and barite; (5) crystalline celestite filling vugs and cavities in the Codroy limestone and (6) veins of celestite in thinly bedded limestone that also contains barite which is difficult to distinguish from celestite. Gypsum was identified in some drill cores. Quartz and residual kaolinite are also reported in interstices between celestite and barite crystals. Minor pyrite, marcasite and galena have also been identified among the nonmetallic minerals.

The genesis of the Port au Port celestite-barite mineralization has been attributed to replacement of the calcareous parts of the Codroy sandy limestone. The celestite-barite mineralization is also characterized by void fillings associated with small veins of celestite in cracks and joints. The larger bodies are irregular in shape but generally conformable with the primary bedding. Mineralization commonly fingers out into the host limestone leaving horses of unreplaced limestone in the ore. Mud and sand impurities from the ore are identical to the insoluble residue of the limestone. Mineralization in the underlying Table Head limestone is limited to narrow veinlets of celestite or sulphides. The Port au Port ores probably formed as a result of meteoric waters percolating through solution channels of the porous, fossiliferous limestone and collecting the elements from the associated evaporites. The ore minerals were then precipitated in the available open spaces under conditions of low temperature and pressure. The host rock is locally brecciated but it is uncertain whether this resulted from solution and collapse activity or later deformation. Marcasite, pyrite and galena are believed to have been introduced later, particularly in the brecciated limestone.

Unclassified Deposits

Rexspar uranium property

The fluorite orebody of the Rexspar (Birch Island deposit (82-51), British Columbia carries fine grained interstitial celestite (see page 156), but mineralogical complexity and low grade make it unlikely that celestite will have economic importance. The sheared feldspathic rock may be a metamorphosed pyroclastic flow, a feldspar porphyry dyke, or arkose, and consequently the author prefers to leave the Rexspar deposit unclassified.

Wilder Property

The Wilder Property (31-89) in Concession 10, lot 7, Bagot Township, Renfrew County, Ontario is accessible from Highway 511, 6.4 km south of Calabogie at the west end of Virgin Lake (Fig. 22). This site is forest-covered with exposures restricted to pits through the thin overburden. According to Guillet (1963) four pits were sunk on the property. These measured 21 by 18 m and 6.5 m deep; 12 by 3 m and 2.4 m deep; 1.2 by 3 m and 0.6 m deep and 2.7 by 1.2 and 1.2 m deep. Bedrock is also exposed in the road that crosses the property.

Spence (1922, p. 80, 81) visited the property and described it as follows: "The celestite occurs in irregular, slab-like masses of radiated, columnar, or fibrous crystals, enclosed in brown dolomite. The dolomite displays indistinct parting planes, which dip 45° to 60° southwest, and appear to be the result of lateral thrust or compression, rather than bedding planes."

The celestite is most abundant near the hanging wall as discontinuous vein-like bodies. It also forms part of the cement in brecciated beds of fine grained, red dolomite. Spence also comments on the occurrence of the celestite: "While the bulk of the celestite masses average from a few inches to one foot thick, exceptionally large masses measuring up to 2 and 3 feet, are sometimes encountered." The dolomite is a fine- to very fine-grained, buff to red rock, locally so porous as to be spongiform and without obvious macrostructures to indicate its origin. The pores are lined by thin brown coatings of quartz crystals. The dolomite is brecciated and the fragments are cemented by white radiating aggregates of celestite crystals at high angles to the wall. There is a narrow calcite-bearing dark brown zone at the base of the celestite that is less than 0.6 cm thick.

In addition to dolomite, which forms the enclosing wall rock, there is an unknown thickness of medium- to coarse-grained calcitic marble that contains a few celestite veins. Locally the marble contains knots and streaks of calcsilicates, that are oriented in a crude foliation at north 80° east with a dip of 40° north. Some of the celestite lenses parallel this foliation. South of the access road the marble is colour banded and aggregates of pyroxene are present in moderately-coarse-grained marble. The author was unable to find the diabase dyke reported by Spence (1922).

Fluorine

Canadian fluorine deposits and occurrences compiled in the data file are fewer than for barium but more abundant than for strontium. Fluorine occurs among the first four elements in 337 of the 733 records in the file. The distributions of associated elements, ore-minerals, gangue minerals, wall rock lithology and wall rock age of fluorine-bearing occurrences are presented in Table 26.

Syngenetic Deposits

Syngenetic fluorine deposits are those that have formed contemporaneously with the enclosing wall rocks during igneous intrusion, extrusion or sedimentation processes. Few of these deposits and occurrences show the effects of wall rock alteration or supergene enrichment strongly enough to disguise the primary genetic processes. The classification used here has a close relationship to the lithology of the wall rocks (see Table 27). None of the Canadian syngenetic deposits is a commercial source of the element but Crystal Mountain, Montana; Asturias, Spain; Rosiclare – Cave in Rock, Illinois and Florida phosphorites are type examples of commercial syngenetic sources of the element. The Canadian examples of syngenetic deposits are however, useful as prospecting pointers that identify areas in which epigenetic veins may be sought.

Igneous Intrusive Rocks

Alkaline Rocks

Fluorite has been reported as a primary accessory mineral and as coatings of miarolitic cavities in some alkaline syenites. Only a few examples are known and none has commercial importance as a source of fluorine. The syenite intrusion on the Wahl prospect (52-96), Thunder Bay, Ontario and the St. Michel sill (31-119) Montreal Island, Québec are examples.

Table 27. Classification of syngenetic fluorine deposits

Classes	Examples
Intrusive igneous rocks Alkaline rocks	Wahl prospect (52-96), Iron Island (31-135), Ont.; St. Michel sill (31-119), Qué.
Felsic rocks	Whiteman Creek (82-29), B.C.; Hasbala lake (64-01), Man.; St. Lawrence, Nfld.; Central City, Colorado; Conway, New Hampshire
Pegmatites	Crystal Mtn, Mont.; Shatford Lake (E-end) (52-98), Man.; MacDonald Quarry (31-87) and Cameron pegmatite (31-136), Ont.
Carbonatite and alkalic rock complexes	Newman complex (31-134), Ont.; St. Honoré (22-04), Qué.; Okorusu, Southwest Africa
Extrusive igneous rock Intermediate flows and pyroclastics	Castel Giuliano, Italy; Rome, Oregon; Spor Mountain Utah
Sediments and sedimentary rocks Clastic sediments	
Eluvial deposits	Asturias, Spain; Rosiclare, Cave-in-Rock, Il.
Alluvial deposits	Muncho Lake (94-11), Alaska Highway, Mile 397-110 Creek (94-10), Bugaboo Creek (82-40), B.C., Hunker and Germaine Creeks (116-01), Yukon Territory; Tampa Bay, Florida.
Bioclastic and biochemical sediments Phosphorites	Lakeland, Florida
Surface waters, groundwaters and brines	Brines in rift lakes, East Africa; Madoc ground waters, Ont.

Felsic Rocks

Fluorite and fluor-apatite are common accessory minerals in many felsic intrusive rocks. Anomalous amounts of fluorine are also carried by a variety of silicate minerals. The minerals are either disseminated through the felsic rock or are concentrated in poorly- to well-defined zones enriched in fluorite or fluorine-bearing silicates. Locally, these minerals also fill miarolitic cavities and coat joint planes.

Granites carrying anomalous fluorine are widely distributed in Canada. Examples include the Rockslide Creek stock (115-2, -3); Seagull stock (105-3) and Cassiar batholith in British Columbia and Yukon Territory; the Nelson batholith and Coryell syenite intrusions in southern British Columbia; the Nueltin Lake granite in Manitoba and Hasbala Lake (64-001) Northwest Territories; phases of the Preissac-Lacorne batholith (north of Val d'Or); the Guenette aplogranite (Campbell Township, Labelle County) and the Wakefield and Onslow syenites in Québec and the St. Lawrence batholith near St. Lawrence, Newfoundland.

None of the Canadian occurrences of syngenetic fluorite in felsic intrusive rocks has proved an economic source of the mineral. One foreign deposit, the Buffalo Mine, Naboomspruit District, South Africa is a commercial source of fluorite (Grogan et al., 1974; Watson and Snyman, 1975). The recognition of fluorite-rich felsic intrusive rocks is important because the producing veins may occur within or near such rocks. Epigenetic veins in syenite have yielded fluorite in the Rock Candy Mine (82-9), Grand Forks, British Columbia, in several small mines in the Madoc District, Ontario and several mines near St. Lawrence, Newfoundland and have been the main Canadian sources of fluorite.

Fluorine-rich, radioactive granites have been reported in Canada and they are a potential prospecting guide to fluorine deposits. Canadian examples include several Nueltin Lake type rapakivi granites in the Baker Lake area, Northwest Territories (LeCheminant et al., 1979, 1980). Foreign examples include the radioactive quartz bostonite at Central City, Colorado and the fluorite-bearing granites of Conway, New Hampshire (Grogan et al., 1974).

Pegmatites

Fluorine is commonly present in pegmatites, mainly as fluorite and rarely as cryolite. Fluorite is also commonly accompanied by a variety of other fluorine-bearing minerals including apatite, topaz, tourmaline and carbonates. Fluorine is generally not enriched in the pegmatitic stage of intrusion but rather in the pneumatolytic stage that follows immediately. This process has resulted in the cryolite-bearing pegmatites that have been mined at Ivigtut, Greenland and Miass, U.S.S.R. It has also given rise to concentrations of fluorine-bearing minerals in greisens and skarns.

In Canada fluorite has been reported in a number of granitic and syenitic pegmatites, notably in southeastern Ontario (Hewitt, 1967a,b; Satterly, 1956, 1957; Thompson, 1943). The pegmatite occurrences include uniform disseminations in massive unzoned bodies, wall-zone or intermediate zone accumulations in zoned bodies and irregular lenses and patches in otherwise massive pegmatites. In detail, the fluorite may be uniformly distributed in the interstices among the salic constituents, fill miarolitic cavities, or be concentrated in one of the pegmatitic zones.

It is reported along with other potentially economic minerals such as cassiterite, at Shatford Lake (52-98), Manitoba (Springer, 1950, 1952), with feldspar in the MacDonald (31-87) and Woodcox (31-88) pits, Monteagle Township, Ontario; accompanying beryllium in the Canadian Beryllium Mine (31-90), Lyndoch Township, Ontario; with uranium minerals in the Faraday Uranium Mine (31-74) at Bancroft, Ontario and in mica pits scattered in pegmatite dykes of the Grenville province (Fig. 12). None of these is a commercial source of fluorite.

In the United States a commercial source of this type is at Crystal Mountain, Montana where fluorite has been mined from concentrations that contain variable amounts of biotite, feldspar, quartz and other rock-forming minerals, in granite or gneiss (Grogan et al., 1974; Sahinen, 1962). Because of the associated minerals and rocks the ores at Crystal Mountain are attributed to a pegmatitic origin.

Carbonatites and Alkaline Rock Complexes

Carbonatites and alkaline rock complexes rarely contain barium and strontium minerals but fluorite or fluorapatite or both are locally abundant. Tonnage and grade are sufficient in a few cases to support an apatite or fluorite mining operation.

The Okorusu deposit. In Southwest Africa (Namibia) is probably the best known example of this category of deposit. It consists of several large lenticular bodies of fluorite in which apatite and quartz occur as accessory minerals. The orebodies which were mined for their fluorite content, occur in a sequence of limestone, quartzite and related rocks that were intruded and metamorphosed by an alkaline syenite stock (Grogan et al., 1974).

The Cargill alkaline complex. In Canada, the Cargill complex which lies southwest of Kapuskasing, Ontario is a potential source of apatite and a possible source of byproduct fluorine (Currie, 1976). The deposit was described by Sandvik and Erdosh (1977), (p. 90): "The Cargill alkalic complex, comprising principally carbonatite and amphibolite rocks, was intruded into the rift system of the Kapuskasing High . . . .

Weathering and leaching under assumed temperate to cool, moist climatic conditions, and controlled by faulting, shearing and/or initial petrographic variations within the carbonatite, developed a small, locally confined karst system in the carbonate rocks and resulted in a thick enriched leached carbonatite zone, capped by troughs and sinks filled with a residuum of apatite, goethite, clay and other minerals stable in the near-surface, oxidizing environment...

Fresh carbonatite contains 5 - 15%, leached carbonatite 20-40% and residuum 20 to 98% apatite."

At Cargill diamond drilling outlined a probable phosphate-bearing deposit of more than 62.5 million tonnes having an average grade of 19.6% P_2O_5 and less than 0.3% MgO (Sandvik and Erdosh, 1977). The fluorine content of the apatite is not given but it is possible that it might be a byproduct of any future production of phosphate.

Other Canadian examples of this type include the Newman deposit (31-134) near North Bay, Ontario (Lumbers, 1971) and the St. Honoré deposit (22-44), near Chicoutimi, Québec (Currie, 1976).

The Newman deposit (31-134). This contains accessory fluorite in the uranian-pyrochlore facies of the complex (Rowe, 1958). The latter consists of an outer zone of potash feldspar-soda pyroxene-quartz rock characterized by many calcite veinlets that also carry soda-pyroxene, soda-hornblende, fluorite, pyrite, hematite and apatite. The inner ring consists of potash feldspar-soda pyroxene-calcite rock with disseminated patches of pegmatitic calcite, soda pyroxene, soda hornblende, potash feldspar laths and fluorite. The core of the complex is not exposed and has not been investigated by drilling. Fluorite is widely distributed through the rocks of the Newman complex but is not sufficiently abundant to have economic significance.

The St. Honoré alkaline syenite-carbonatite complex (22-4). This is a niobium producer. The niobium ore and other associated carbonate rocks carry from 8 to 12 per cent apatite and accessory amounts of fluorite, barite and rare earth minerals. Analyses of the apatite have not been published so the potential byproduct fluorine content is unknown.

Silver Crater-Basin deposit, Ontario. Traces of fluorite have been reported in the carbonatite lens of the Silver Crater-Basin deposit (31-77) near Bancroft, Ontario (Rowe, 1958). The mineralogy of the host rock, the presence of soda metasomatism, niobium and uranium support a carbonatite origin although the question is by no means settled.

Igneous Extrusive Rocks

Intermediate Flows and Pyroclastics

Stratiform fluorite deposits in polymictic lacustrine sediments of volcanic origin have been reported from north of Rome (Castel Giuliano), Italy; near Rome, Oregon; and at Spor Mountain, Utah (Lindsey, 1975; Grogan and Montgomery, 1975; Sheppard and Gude, 1969). The fluorite is very fine grained and disseminated quite uniformly through sedimentary beds. Of the Rome, Oregon deposits, Grogan and Montgomery (1975), (p. 662) wrote: "Near Rome in the southeastern part of the state (Oregon), fluorspar occurs as submicroscopic, nearly spherical grains less than 1 μ in diameter in volcanic tuff, tuffaceous mudstone, and mudstone of Tertiary lake deposits. The fluorspar content reaches 16% in some zones, but is generally lower than that. The tonnage of contained fluorspar is conservatively estimated at 11 million tonnes. Because of the very fine particle size of the fluorspar, concentration to acceptable grade has not proved practical."

Of the Rome, Italy deposit, the same authors (ibid, p. 664) reported: "The Pianciano deposit in the Castel Giuliano area 40 km north of Rome consists of fluorspar impregnating somewhat contorted beds of volcanic ash apparently deposited in a geologically recent lake. The fluorspar content ranges from 35% to 55% and the fluorine is thought to have been derived from volcanic emanations along with barium, strontium, and phosphorus. The fluorspar is too fine-grained to be recovered by flotation, but tests indicate it may be feasible to make a 70% product for metallurgical use by hydrocyclone separation. Reserves on one property alone are said to be on the order of 8 million mt."

The reserves and grade of these deposits are attractive but the technical difficulties in making a useful concentrate have delayed their exploitation. Mineralization is attributed to fluorine-rich exhalations derived from volcanic centres that deposited fluorite in water-lain pyroclastic rocks of intermediate to felsic composition. Such deposits have not been recognized in Canada.

Sediments and Sedimentary Rocks

Eluvial Deposits

Eluvial deposits of fluorite have been described from the United States and Spain. Minor fluorite was recovered from residual deposits overlying economic and subeconomic fluorite veins in the Cave in Rock – Rosiclare district of Illinois and Kentucky (Weller et al., 1952). Near the surface fluorite veins, especially those having limestone wall rocks, were decomposed by surface water moving downwards through shattered wall rocks. The waters dissolved the limestone and calcite gangue leaving aggregates of insoluble fluorite, clay and wall rock boulders called "gravel-spar". This natural beneficiation process upgraded otherwise noneconomic veins, making them profitable to mine. The deposits extend down from the base of the surficial soil to a depth of 45 m or more before solid veins and wall rock are encountered. Some of the deposits show the effects of creep down subsurface slopes thus altering the distribution of the fluorite ore (Weller et al., 1952).

A similar occurrence of fluorite is reported over the epigenetic fluorite veins in the Asturias District of Spain. Some fluorite is recovered from the residual soil overlying fluorite veins but most of the production is won from bedrock veins.

Commercial deposits of this type are unknown in Canada, presumably because such soils were removed by glacial erosion during the Pleistocene Epoch; however unglaciated areas such as those in western Yukon Territory or protected depressions in bedrock surfaces are potential sites of this type of deposit.

Alluvial Deposits

Transported (alluvial) deposits and occurrences are known in a few places in central Yukon Territory, northeastern and southeastern British Columbia, St. Lawrence, Newfoundland and the western United States. Fluorite and barite have been reported in alluvial unconsolidated placers on Hunker and Germaine creeks (116-1), Yukon Territory (Gleeson, 1970). Lag or alluvial fluorite occurrences have been reported in northeastern British Columbia in creeks near Muncho Lake (94-11) and in the Alaska Hwy Mile 397-110 Creek area (94-10) in Recent stream detritus. At both sites it is closely associated with barite derived from stratiform bodies, vein and solution cavity fillings eroded from the Devonian formations crossed by the stream valleys (Taylor and Stott, 1973).

Bugaboo, Vowell and Forster creeks. Fluorite is present along with other minerals such as allanite, andalusite, apatite, epidote, garnet, hematite, ilmenite, magnetite, pyrite, sphene and zircon in recent placers on Bugaboo, Vowell and Forster creeks (82-40), in the Spillamacheen district, southeastern British Columbia (Rowe, 1958). The minerals were weathered from the Bugaboo and Horsethief granite stocks (Reesor, 1973) and subsequently concentrated in creek bars.

Alluvial fluorite was also identified in glacial tills overlying bedrock fluorite veins in the area north and west of St. Lawrence during the search for hidden fluorite veins. The mineral is distributed in the base of the till either directly over the veins or displaced in cases where bedrock topography contributed to down slope creep away from the veins. Soil analyses identified the fluorite concentrations, none of which were of economic importance (Tilsley, 1975).

Unconsolidated placers form creek or dry wash deposits that contain fluorite several kilometres downstream from the nearest bedrock source. These occurrences characterize some areas in the Cordillera of the western United States. Although none of these have economic importance, they may provide a valuable guide to prospecting for veins in the underlying bedrock.

Chemical Sediments

The minor fluorine content reported in carbonate rocks has been traced either to mineralogical or organic hosts. Fluorine is concentrated in detrital grains of apatite, mica, hornblende and clay minerals. Although not economically important in themselves, such occurrences may have been the source of fluorine subsequently leached and transported by pore solutions and groundwater to form veins and replacement bodies of greater economic importance.

The minor fluorine content of other carbonate rocks is concentrated in the phosphate component of bones, teeth and brachiopod shells. Bones continue to take up fluorine from waters after the death of the organism and the fossil remains are enriched (Graf, 1960). The fluorine content of fossiliferous carbonate rocks rarely exceeds that of fluorine held by the fluorapatite in the fossils. Fluorite is also reported with algal fossils in certain limestones (Graf, 1960). None of these occurrences reach economic size and grade but they are probably another source of the fluorine deposited as fluorite in fissure veins.

Biochemical Sediments (Phosphorites)

Fluorapatite, containing four per cent fluorine, is a common but not the only phosphate mineral constituent in phosphate rocks of sedimentary origin or enriched residual deposits resulting from the weathering of such rocks. Phosphorite beds, the main source of phosphorus used in chemical fertilizers, have world-wide distribution and thus represent potentially the world's greatest source of fluorine. In North America phosphate rock is mined in Florida, Tennessee and Idaho (Christie, 1978). No commercial sites are presently known in Canada although thin uneconomic beds have been reported in southeastern British Columbia (Price, 1961, 1965). Pressure for environmental protection from fluorine emissions during the processing of phosphorites has spurred research into fluorine recovery technology and consequently there is considerable production of fluor-silicic acid by American fertilizer factories. The acid is used in preparation of the electrolyte used in the alumina-aluminum reduction process and to a lesser degree of fluorine-based chemicals.

Phosphorites commonly occur as thin beds of large areal extent in conformable marine shale and limestone sequences. Other phosphate beds are related to shallow water deposition on unconformity surfaces that transgress underlying sedimentary rocks. The common association with black shales and limestones, the fossil species present, the abundance of pyrite and marcasite and the fetid odour when specimens are broken all indicate deposition in an anaerobic environment. The Florida and Tennessee deposits have been enriched by residual weathering to develop residual or transported pebbles of phosphate in a matrix of phosphate and clay. The phosphate ranges from very fine grained to amorphous, brown to black material. Optical identification of constituent minerals is difficult but they probably consist of a mixture of apatite and fluorite replacing fossil debris and associated clay, carbonates, chalcedony and hydrocarbons.

Tennessee. Phosphate rock has been mined in Tennessee since 1893. The phosphate is mined from residual eluvial deposits developed on the phosphate beds of the Ordovician Hermitage, Cannon, Bigby and Liepers Formations. The residual blankets are enriched as a result of leaching and weathering which removed the calcite matrix and dissolved and redeposited the phosphate. One of the mining areas lies near Mount Pleasant, Tennessee (Smith and Witlach, 1940).

Florida. Production is obtained from land-pebble phosphate in Quaternary sands, in the lower unit of the Pliocene Bone Valley Formation and in the residual calcareous clay of the Miocene Hawthorn Formation (Cathcart, 1964). Mineable beds in the latter consist of fine grained, brown and amber phosphate nodules in a calcareous matrix. Rounded, highly polished phosphatic nodules are present in all facies of the Hawthorn Formation. The nodules were deposited as primary constituents of the limestone or formed as a result of contemporaneous replacement of shells or oolites in the limestone in a shallow marine environment. They have been subsequently subjected to weathering and concentration as a result of solution and removal of the limy matrix. Subsequently the sea readvanced and reworked the residua, limestone boulders were phosphatized, and all were incorporated in the base of the Bone Valley Formation. The calcareous fluorapatite nodules are mined from the calcareous clay that forms the top of the Hawthorn and the base of the Bone Valley Formations. The calcareous clay, which included primary nodular phosphorite in limestone was subsequently weathered to form residual soils enriched in phosphorus. This type of phosphorite has not been reported in Canada, presumably because glacial erosion in the Pleistocene would have removed any such deposits formed.

Utah, Idaho, Wyoming and Montana. The Permian Phosphoria Formation of Utah, Idaho, Wyoming and Montana is one of the best known and widespread phosphorites in the United States. It is a phosphatic shale composed mainly of dark, carbonaceous, phosphatic and argillaceous beds 46 to 60 m thick (Cressman, 1964). Mudstone and phosphorite are the end members; dark dolomite and limestone are minor constituents.

British Columbia. Although phosphate beds outcrop in southeastern British Columbia they have not proven economic sources of fluorine in fluorapatite (Price, 1965; Kenny, 1979). Four Upper Devonian to Jurassic, subeconomic phosphorite beds have been studied in the Rocky Mountain Thrust Belt between the US-Canada border and Jasper. They have been described by Kenny (1979) as follows:

1. Mississippian phosphate horizon (ibid, p. 7-8) – "the pelletal phosphate is a black, fine-grained rock with a bituminous odour when struck with a hammer. On weathered surfaces, it often shows a bluish to whitish "bloom". It assays from 9.0 to 25% P_2O_5 and occurs as dense, fine-grained nodules scattered thorughout the shale".

2. Ishbel Phosphate horizon (ibid, p. 8) – "Thin sections show the rock to be composed of varying amounts of phosphate pellets and quartz grains set in a calcareous matrix. The pelletal phosphate often contains small clasts of micro-aggregates of pyrite and ferruginous material (probably weathered pyrite)."

3. Basal Fernie phosphate horizon (ibid, p. 9) – "Thin sections show the pelletal phosphate to consist of phosphate pellets and a minor amount of concentrically banded phosphatic oolites set in a calcareous matrix stained with brown phosphatic material."

4. Phosphatic belemnite bed (ibid, p. 9, 14) – "Within the Rock Creek Member of the Fernie Group, there exists a five to 20 foot bed of black, carbonaceous sandstone containing a large number of fossil belemnites. This bed, which lies 150 to 250 feet above the base of the Fernie Group, assays 3.2 to 16% P_2O_5 (Telfer, 1933). In places, this sandstone contains some phosphate pellets and/or phosphate nodules."

Surface Waters, Groundwaters and Brines

Fluorine-bearing waters and brines have been collected and analyzed from northeastern British Columbia, southern Ontario, St. Lawrence, Newfoundland, and East Africa. Anomalous amounts of fluorine have been reported in hot springs at Liard Crossing, British Columbia (Brandon, 1964). This calcium-sulphate-rich water emerges from Devono-Mississippian and Devonian shales and limestones that have intraformational breccia zones cemented by fluorite and witherite (e.g. GEM showings, Fig. 25). The showings of Liard Fluorspar Mines Ltd. extend 16 km north from the GEM showing (94-16).

Surface water and groundwater anomalies were identified in the Madoc, Ontario area (Lalonde, 1973) (Fig. 26). The alkaline surface waters contain from 60 to 420 ppb fluorine and average 126 ppb and it was determined that the element travels several kilometers in stream waters from known sources. The fluorine content of neutral to slightly alkaline groundwaters ranges from 20 to 1800 ppb and averages 105 ppb. Groundwater in limestone contains significantly greater fluorine concentrations than that in other rock types in the area. Three groundwater samples from limestone showed fluorine values between 1700 and 1800 ppb, which is sufficient to present a health hazard. Fluorine does not occur in sufficient concentration in this environment to permit economic recovery.

As noted earlier the search for hidden fluorite veins in the St. Lawrence area of Newfoundland involved analyses of a number of sample media, including groundwaters. Anomalies were found that aided in the discovery of blind veins (Tilsley, 1975).

Groundwaters and hot brines have been analysed from various sources along the rift zones of East Africa. A recent study in Ethiopia to identify suitable areas for geothermal electricity generation tabulated analyses of these waters which in several sites are bicarbonate-fluorine rich (United Nations Development Program, 1973). Although much work has been done on fluorine-bearing waters no concentrations have been identified that are potential economic sources of the element.

Epigenetic Deposits

Canadian epigenetic fluorine deposits consist of either fissure veins or replacement bodies formed subsequent to the consolidation of the wall rock (Table 28). The mineral constituents were deposited from solutions that derived the elements by leaching from adjoining wall rocks or from some distant source. Canadian fluorite production has come mainly from fissure veins and the principal source has been the fissure veins in the St. Lawrence granite, Newfoundland and similar veins in Paleozoic and Proterozoic sedimentary rocks and gneisses near Madoc, Ontario. Canadian examples are used to illustrate the deposit types.

Fissure Fillings

Fluorite occurs in fissure-filling veins in British Columbia, Ontario, Québec, Nova Scotia, Newfoundland and abroad. The veins occur in a variety of sites ranging from tectonically formed dilatant zones to solution cavities in carbonate rocks, and in wall rocks of various ages and compositions.

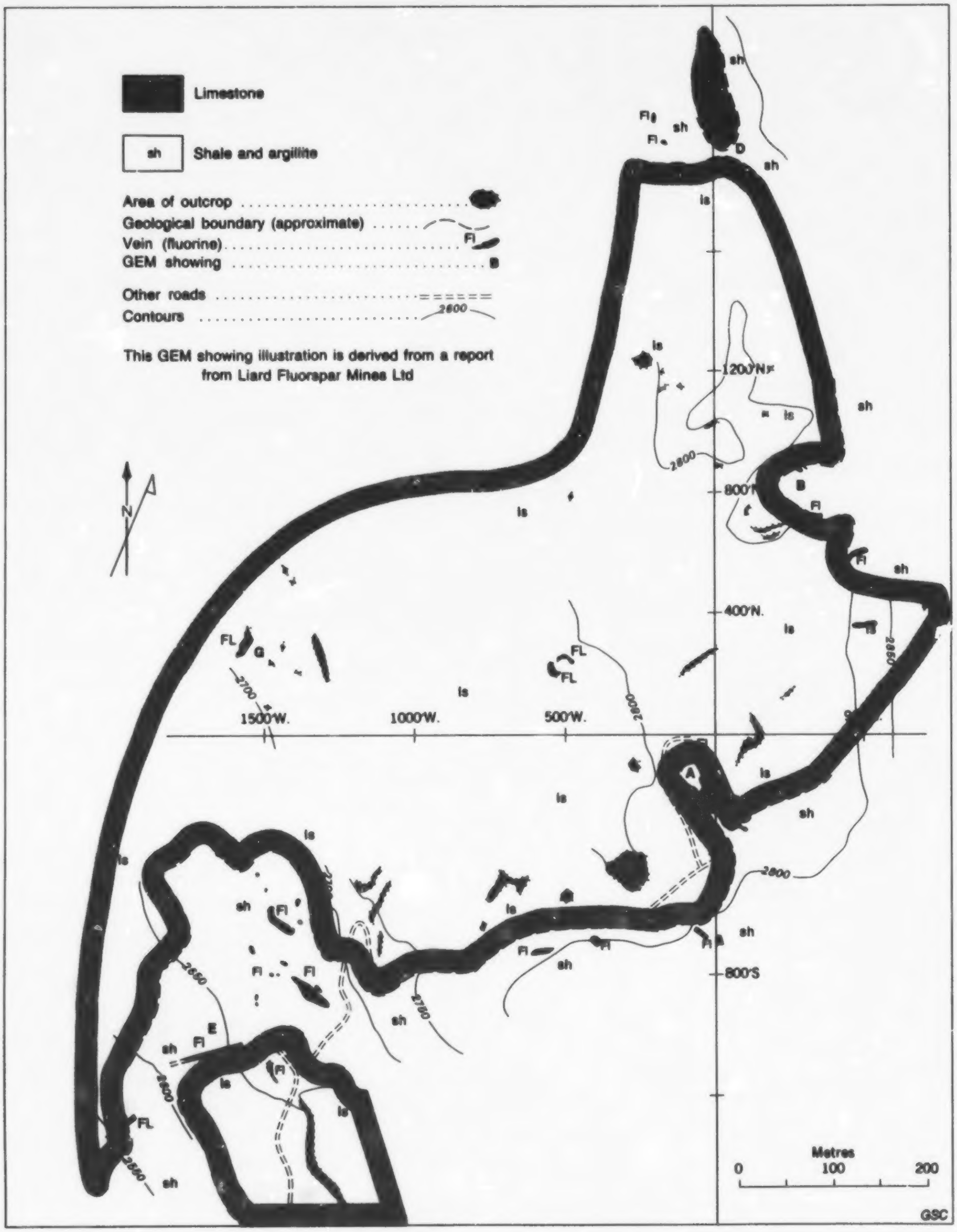

Limestone
sh Shale and argillite
Area of outcrop
Geological boundary (approximate)
Vein (fluorine) Fl
GEM showing B
Other roads
Contours 2800
This GEM showing illustration is derived from a report from Liard Fluorspar Mines Ltd
N
ls
sh
Fl
FL
B
D
E
G
A
1200'N.
800'N.
400'N.
800'S
1500'W.
1000'W.
500'W.
2600
2650
2700
2800
2850
Metres
0
100
200
GSC

Figure 25. *The GEM showing (Liard Fluorspar Mines Ltd.) north of Liard Bridge, Alaska Highway, British Columbia.*

British Columbia

The British Columbia properties include the potentially economic Liard Fluorite property in the northeast and the Rock Candy Fluorite Mine, a small past producer near the U.S. border at Grand Forks (Fig. 27).

Liard Fluorite property. At the first locality three claim groups – Coral (Liard Crossing, 94-18); Tee (Liard Crossing, 94-21) and the GEM (Liard Crossing, 94-16) (Fig. 25) are parts of a single property on which diamond drilling has outlined fluorite-witherite mineralization related to breccia zones at the contact between late to middle Devonian Besa River and Dunedin Formations (Woodcock and Smitheringale, 1957; Holland, 1954). The mineralization is diluted by quartz and shale fragments. Inaccessibility and high transportation costs hinder development and future production.

Rock Candy Fluorite Mine. The Rock Candy Fluorite Mine (82-09, Fig. 27, Spence, 1922), 24 km north of Grand Forks at the south end of the Omineca Crystalline Belt in the Cordilleran Orogen (Map 1588A). Fluorite was mined from a vein that cuts through a syenite intrusion and rocks of the Phoenix volcanic unit. The syenite has been correlated with the Coryell intrusions of Paleocene or Eocene age (Little, 1957), and consists mainly of orthoclase (some of which may be barium-rich), minor plagioclase, biotite, hornblende and augite with traces of quartz, apatite, sphene and zircon. The greenish black volcanic rocks contain very fine grained felted aggregates of albite-oligoclase and actinolite with minor magnetite, biotite and quartz. The primary constituents have been largely replaced by chlorite and calcite. The syenite is cut by a series of pale green, porphyritic dykes that carry visible crystals of fluorite. Both the syenite and the dyke rocks have been altered in the vicinity of the fluorite veins.

Structures in the mine area include dilatant fissures in a north trending zone of fractures represented by a topographic lineament that can be traced from Fluorine Lake south to Kennedy Creek. The fluorite ore occurs in a mineralized shear zone and adjoining fractures at the contact between the syenite and the mafic dyke rocks. The zone may mark an unmapped fault. The individual fractures are subparallel and the mineral fillings pinch and swell along strike. The veins occupy fissures that range in width from 2.5 to 3 m and are locally so closely spaced that widths up to 12 m have been mined. The surface exposures are more than 150 m in length and mineralization has been traced to a depth of 120 m beneath the present workings. The ore is attributed to the end products of crystallization of the enclosing syenite.

The veins contain fluorite, barite, chert and quartz in that order of abundance, with minor to trace amounts of calcite, pyrite and kaolinite. The fluorite is pale green to colourless and rarely pink. Numerous cavities and vugs are encrusted with crystalline fluorite, barite, calcite, quartz and fine grained octahedra of pyrite on crystal faces of the nonmetallic minerals. The barite occurs in yellow, transparent crystals to 10 cm long lining cavities. Cream coloured chert in the ore contains scattered crystals of fluorite and quartz.

Ontario

Thunder Bay. A number of fluorite-bearing veins are present in the Thunder Bay, Madoc and Cardiff areas, Ontario (Tanton, 1931, Franklin, 1970; Guillet, 1964; Sangster, A.L., 1970; Fig. 16). As described earlier in this report (see barite) barite and fluorite in the Thunder Bay district are associated with silver and other metals where mineralized veins and faults cut Keweenawan diabase sills within a thick succession

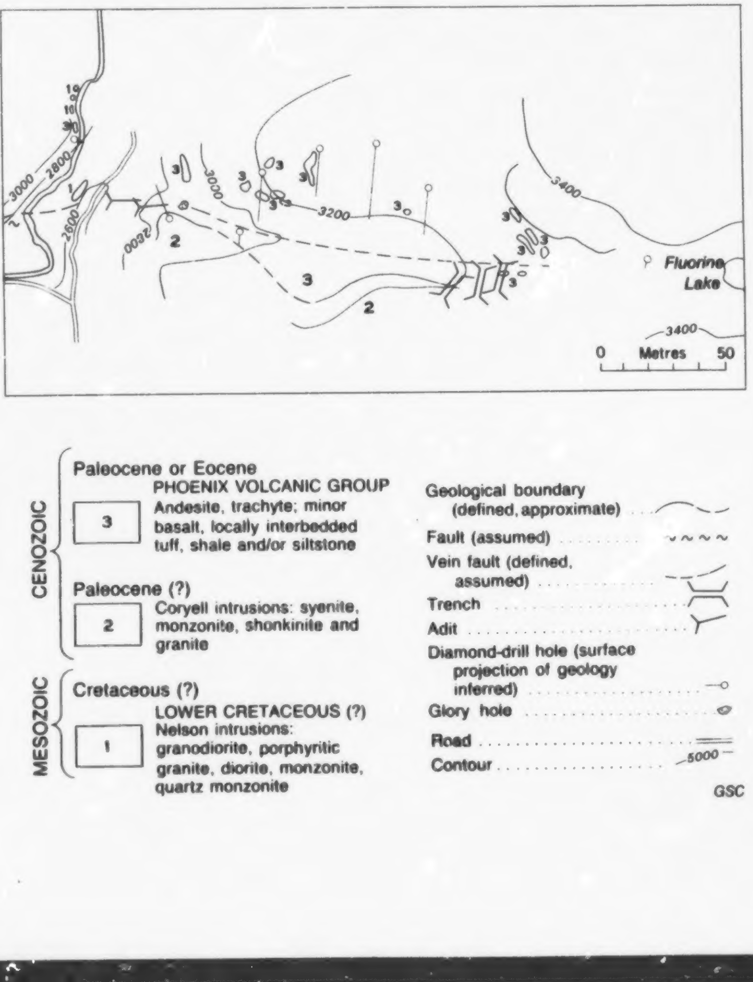

3000
2800
2600
3000
3200
3400
3400
1
2
3
Fluorine Lake
0 Metres 50
CENOZOIC
Paleocene or Eocene
PHOENIX VOLCANIC GROUP
3 Andesite, trachyte; minor basalt, locally interbedded tuff, shale and/or siltstone
Paleocene (?)
2 Coryell intrusions: syenite, monzonite, shonkinite and granite
MESOZOIC
Cretaceous (?)
LOWER CRETACEOUS (?)
1 Nelson intrusions: granodiorite, porphyritic granite, diorite, monzonite, quartz monzonite
Geological boundary (defined, approximate)
Fault (assumed)
Vein fault (defined, assumed)
Trench
Adit
Diamond-drill hole (surface projection of geology inferred)
Glory hole
Road
Contour
5000
GSC

Figure 27.

Geology of the Rock Candy Fluorite Mine, Grand Forks, British Columbia.

of Aphebian, Animikie Group and Helikian Sibley Formation shales. Fluorite and barite combine with quartz, calcite and rock fragments as gangue constituents in the silver veins. Wall rock alteration is proportional to the width of the vein and the ores have been introduced as a result of intrusion of the Keweenawan diabase (Franklin, 1970).

The Creswel (Porcupine) Mine (Fig. 16) is a recent combination of the Porcupine (52-25), Badger (52-26), Keystone and Silver Creek (52-29) properties and is an example of the Thunder Bay type silver mineralization with which barite and fluorite are associated. The Creswel (Porcupine) Mine produced 1132 kg of silver from a single vein that occupies a post-Keweenawan fault cutting Aphebian Animikie shale in the lower levels of the mine and Keweenawan gabbro in the upper levels. The mineralization fills dilatant zones along the fault and is locally diluted by horses of shale. In terms of value, the major minerals are silver and argentite associated with quartz and calcite and minor galena, sphalerite, chalcopyrite, barite, fluorite and witherite. Neither barite nor fluorite concentrations attain ore grade.

As noted earlier, fluorite occurs with barite in the west end of the Silver Mountain Mine in Thunder Bay District. Fluorite, although widely distributed, does not reach economic proportions. The other properties in the Thunder Bay District – Big Bear vein (52-35), Elgin vein (52-36) and the Augusta mine (52-11) – that were explored for silver and base metals, carry fluorite along with barite as gangue minerals. Mineralization – chiefly native silver, argentite, galena, sphalerite, pyrite, fluorite, barite, calcite and quartz – fills dilatant zones along vertical post-Keweenawan faults, cutting Animikie shales, and in the case of the Augusta Mine, Keweenawan diabase. None of these veins proved economic.

The Madoc area. This was a source of fluorite from epigenetic calcite-fluorite-barite veins until 1961 (Wilson, 1921; Guillet, 1964; Hewitt, 1968) (Fig. 26). The area is underlain by the Deloro and Moira granite stocks that intrude Grenville Supergroup marble, volcanic and metasedimentary rocks that were deformed and deeply eroded before Paleozoic time. The Grenville rocks are overlain with angular unconformity by up to 60 m of flat-lying Paleozoic arkose and limestone beds. Wall rocks of the veins include marble, granite, Paleozoic limestone and andesite in that order of abundance. The rocks are cut by the Moira Lake fault, a weakly sinuous, nearly vertical fracture zone traceable northwesterly for 5.6 km. Fluorite and other minerals occupy lenticular dilatant zones, resulting from movement along the Moira Lake fault and the Lee-Miller fracture system in southwestern Madoc Township. The ore ranges from 50 to 70 per cent fluorite, calcite and barite with minor celestite, quartz, marcasite, pyrite, sphalerite and other sulphides. No consistent order of deposition is apparent but quartz, sulphides and celestite occur most frequently in the wall-zones and mineralogical banding shown by fluorite, calcite and barite in bands ranging from less than one centimetre to over 10 cm suggests rhythmic deposition. Wall rock fragments, some of which are replaced by fluorite, are also common. Material carrying from 50 to 75 per cent fluorite and having calcite as the main gangue constituent was mined profitably. The calcite content increases with depth and in narrower zones along veins. The barite content increases relative to the fluorite content in a southerly direction along the Moira Lake fault. Combined amounts of quartz, celestite and metallic sulphides rarely exceed five per cent of the vein material.

The main fluorine production in the Madoc area came from the Perry Lake (31-16, -17) property; Rogers Mine (31-21) and Noyes Mines (31-12) along the Moira Lake fault. The Lee Senior (31-20), Lee Junior (31-34) and the Blakely Mine (31-13) occur west of the Moira Lake fault and may be related to the Lee Miller fracture system.

The Perry Lake (31-16) – Perry mine (31-17) vein strikes N 60°W and dips steeply northeast. The vein fracture, which is continuous between the two mines, is largely barren of ore. Consequently, the two mines were not joined during mining operations (Guillet, 1964). Fluorite of the Perry Lake vein was mined to a depth of 50 m from a series of lenses, individually less than 83 m long, filling dilatant zones along the Moira Lake fault. Near surface the veins form a stockwork that coalesces into larger and more productive lenses at depth. The ore consists of fluorite, calcite, celestite, barite, pyrite and minor amounts of metallic sulphides. The wall rocks are banded grey Grenville marble and pink or grey granite.

The Rogers mine (31-21) is 0.8 km northwest of the Perry properties along the Moira Lake fault. The vein strikes N 65°W with minor variations. It was worked to a depth of 72 m and along strike for 225 m. The ore came from a single large northwest raking orebody that averaged 5.4 m thick and had a minimum economic width of 0.5 m. The ore is known to continue beneath the 72 m level. It consisted of fluorite, barite, calcite, celestite and minor metallic sulphides. In some parts of the vein celestite occurred on the walls, followed by an intermediate zone of banded barite and fluorite, and a massive calcitic core.

The Noyes mine (31-12) lies on the Moira Lake fault south of Madoc (Guillet, 1964; Fig. 26). Total past production is estimated at 25 300 tonnes of fluorite. In the Noyes area the Moira Lake fault strikes N 50°W, dips vertically and shows a horizontal offset of between 22 and 30 m. The vein occurs in the Hadrynian Moira granite for most of its developed length but penetrates Ordovician Black River sedimentary rocks to the south. The ore zone ranges from one to 60 m in length, averages 2.4 m thick and has been mined to a depth of 83 m. The ore is a mixture of fluorite and barite in which the barite content increases down dip and along strike to the south.

The Lee Junior (31-34) fluorite vein is in Black River limestone at its south end and Precambrian black rhyolite at its north end (Guillet, 1964). The vein lies parallel to, but west of, the northwesterly trending Moira lake fault. An estimated 2218 tonnes of fluorite were produced between 1917 and 1941. The mineralization consisted of fluorite, barite and calcite and minor amounts of pyrite and quartz. Half of the material mined was discarded as too low grade.

The Lee Senior (31-20) and Blakely (31-13) mines are similar and are associated with the Lee-Miller fracture zone west of Moira Lake fault.

Cardiff Township. In Cardiff Township, Ontario east of Wilberforce, northeast-trending calcite-fluorite-apatite-silicate veins occur in a belt of calc-silicate rocks containing syenite intrusions. The veins contain variable amounts of calcite, fluorite, apatite, pyroxene, hornblende, mica, feldspar and traces of molybdenite, scapolite and sphene (Fig. 12). The Cardiff Uranium Mine (31-73, -75), Richardson (Fission) Mine (31-78), Trip Farm (31-79) and Dwyer deposits (31-82) represent this class of veins, with the veins of the Cardiff property being typical in their general characteristics of all veins of the group.

The Cardiff Uranium Mine (31-73, -75) holds claims in concessions seven to nine at the west boundary of Cardiff Township, southeast ot Wilberforce, Ontario, (Fig. 22). The area is underlain by Proterozoic paragneiss and syenitic gneisses of the Grenville Supergroup that trend north through the mine property and then bend to the northeast between Wilberforce and Harcourt around the northwest part of the Cardiff Plutonic complex. Uranium-fluorite ore has been identified at five sites over a distance of 2700 m along the contact between the metasedimentary rocks and syenite gneiss (Guillet, 1964, p. 8). Work at the five sites has exposed mineralized calcite-fluorite-apatite veins or fluorite-bearing syenite pegmatites that are, in many cases, conformable with the gneissic banding.

Vein mineralization ranges from coarsely crystalline and massive to very fine grained and strongly banded. Movement along some veins following deposition resulted in marked size reduction of the calcite-fluorite aggregates both with and without attendant strong fluxion textures. In the first case the aphanitic parts vary from purple mixtures of calcite and fluorite to thin alternating bands of crushed fluorite and calcite with or without minor small augen of the other vein constituents. In the second case, there is a strongly developed fluxion texture encasing subrounded fragments of apatite, hornblende, biotite, feldspar, uraninite and less commonly rock fragments. The mylonitic or cataclastic products are commonly associated with the walls of the wider veins and a few of the narrower veins are completely filled by the same material.

The principal minerals include fluorite (20-30%), calcite, apatite, and minor hornblende, biotite, pyroxene, feldspar, scapolite and magnetite. Accessory minerals include sphene, zircon, allanite, pyrite, pyrrhotite, molybdenite, uraninite, uranothorite, thorite, pyrochlore and betafite. Well-terminated crystals of hornblende, biotite, feldspar, apatite, titanite and scapolite have grown into the veins from the walls. The fluorite, as is so typical of these veins, is photosensitive and will bleach grey after a year's exposure to sunlight.

The paragenesis is a complex combination of pegmatite formation overlapping with hydrothermal activity related to regional syenitization of paragneisses and the emplacement of the Cardiff Plutonic Complex. the pegmatites, described as replacement type (Hewitt, 1967a, b), consist of pyroxene, abundant feldspars, calcite, fluorite and minor quartz emplaced in syenitized gneisses. Uraninite and uranothorite crystallized during the pegmatite phase, whereas calcite-fluorite-apatite veins commenced to form at the close of the pegmatite phase and continued to form for sometime afterwards. The veins are irregular, narrow and lenticular and range from a few centimetres to 3.6 m in thickness and up to 90 m in length. They are highly variable in composition, both along strike and down dip. The veins have been interpreted as hydrothermal fissure fillings in syenitized gneisses, amphibolites and less commonly in silicated marble.

On the Richardson property lenticular veins strike northeast and dip 20 to 50 degrees southeast at a low angle to the gneissic banding (Fig. 22). Vein material consists mainly of white to grey calcite, deep purple fluorite, and green or brown apatite. Post-mineralization shearing has granulated the vein constituents, producing augen of undeformed apatite and magnetite crystals in a fine grained matrix of fluorite and calcite. The property was also investigated as a source of uranium but neither fluorite nor uraninite concentrates have been produced.

The veins on the Cardiff Uranium Mine, Richardson and other properties between the mine and Harcourt were first developed as a source of fluorite (Guillet, 1964). In the late 1940s and early 1950s the properties were again re-opened as a possible source of fluorite-uraninite ore; however high milling costs coupled with small reserves made mine operations impractical. Several other properties, which are geologically and mineralogically similar, are distributed across the northwest corner of Cardiff Township (Fig. 22). In addition to the previously-mentioned Cardiff, Richardson and Tripp Farm they include: Cardiff Tp (31-83), Montgomery (31-80), Dwyer (31-82), Schickler Farm (31-81), Clark (31-84) and three unnamed properties. It is unlikely that more than 200 tonnes of uranium-fluorite ore was produced in total from these properties.

Québec

Lacorne Townships. In northwestern Québec the Lacorne Mine (32-07), north of Val d'Or has fluorite as a minor constituent of epigenetic veins that cut through pegmatite dykes (Map 1588A). Fluorite occurs here in an en echelon set of veins that strike N 60°E to N 80°E and dip 50° southeast (Tiphane, 1972). They were mined for molybdenite and bismuthinite and the fluorite was discarded. The veins, ranging in width from 30 cm to 2 m, fill fissures in pegmatite and consist of white feldspar, quartz, variable amounts of molybdenite, muscovite and accessory fluorite. Two other occurrences, Goyette-Sup (32-10) and Lacorne Tp (32-08) in Lacorne township, are reported to have subeconomic molybdenite and fluorite gangue in epigenetic veins in pegmatite.

Newfoundland

St. Lawrence. Fluorite veins immediately west of St. Lawrence, Newfoundland, at the south end of Burin Peninsula, are another example of epithermal veins in granitic rocks (Fig. 28). Until closed in 1978, the St. Lawrence mines of ALCAN Limited were Canada's only fluorite producers. Fluorite was produced from three mines Tarefare (1-21), Director (1-22) and Blue Beach (1-23), located immediately west of the village of St. Lawrence. The mines are accessible by an all weather road from Marystown and by sea at St. Lawrence. The mineralized belt ranges up to 10 km in width, extends 30 km inland from the coast and contains more than 30 mineralized occurrences. The area has a discontinuous cover of unconsolidated Recent and glacial deposits up to 12 m thick, and is dotted with shallow ponds, adding significantly to the cost of exploration for additional fluorite deposits. According to Strong et al., 1976, (p. 2): "The area is dominated by Precambrian rocks, the mainly sedimentary Rock Harbour Group and the mainly volcanic Burin and Marystown Groups. Latest Precambrian to Middle Cambrian rocks of the Inlet Group form a discontinuous belt in the eastern part of the map area. There are large areas of granitic intrusive rocks, some equivalent to the Precambrian Marystown Group volcanics and some to the Carboniferous St. Lawrence Granite. Mafic dykes, most abundant in the Burin Group, are thought to range from Burin Group equivalents to those cutting the St. Lawrence Granite. The structural history of the area was mainly one of southeasterly directed thrust faulting which took place between Middle Cambrian and Carboniferous time. The fluorite deposits at St. Lawrence constitute the main economic deposits, but numerous showings of a variety of minerals occur throughout the area."

The fluorite deposits of the St. Lawrence area are in the Carboniferous St. Lawrence granite that intruded Cambrian and Precambrian volcanic and sedimentary rocks (Teng and Strong, 1976). The stratigraphy of the area is outlined in Table 29.

The main wall rock of the fluorite veins, a peralkaline alaskitic granite with a rhyolite porphyry facies and having chilled contacts with overlying slates, is characterized by a high content of unaltered pink potassium feldspar, albite and quartz, and minor to trace amounts of riebeckite, fluorite and aegirine. The granite is locally porphyritic or miarolitic and the miarolites are encrusted with quartz, orthoclase, plagioclase, green biotite, magnetite, riebeckite, hematite, calcite and fluorite crystals.

Table 28. Classification of epigenetic fluorine deposits

Classes	Examples
Fissure Fillings	Liard Crossing (94-16, -17, -21); Rock Candy Fluorite Mine (82-9), B.C.; Creswel (52-25); Silver Mtn. (52-13); Silver Islet (52-33); Perry Lake (31-16); Rogers Mine (31-21); Noyes Mine (31-12); Lee Junior (31-34); Blakely (31-13); Cardiff Uranium Mine (31-73, -75), Tripp Farm (31-19), Ont.; Lacorne Molybdenite Mine (32-07), Qué.; Macmillan (11-48), N.S.; Tarefare (1-21), Director (1-22) and Bluebeach (1-26), Nfld.; Buffalo Mine, South Africa.
Replacement Deposits	Mexico; Derbyshire, England
Skarn and Greisen Deposits	Canada Tungsten Mine (105-12); Fiddler Yukon (105-5), Yukon; Low Grade claims (104-16); Blue Light Claims (104-19), B.C.; Burnt Hill (21-42) and Mt. Pleasant (21-18), N.B.; Lower Canoe Lake (21-04), N.S.
Unclassified	Rexspar (Birch Island) 82-59, B.C.

The fluorite veins occupy fault fissures up to 3.2 km long and related gash fractures in or near the granite batholith. Two sets of fissures are present – a northerly striking set, N 40°W to N 20°W that dips between 60 and 80 degrees east and a westerly striking set, S 70°W to N 70°W. The faults show evidence of greater horizontal than vertical components of movement. The north-south veins mined in the Director, Tarefare and southern Blue Beach mines are longer than the east-west veins but the latter have greater ore widths. Mineralization has been traced up to 3.2 km with widths up to 30 m and normal widths between 2 and 7 m. The veins extend only a limited distance into the covering slate which serves as an impermeable barrier overlying the granite. The veins have sharp walls, slickensides and gouge, vugs and breccia zones cemented by fluorite and other minerals. The ore is not continuous but occupies dilatant zones along the faults.

The veins carry fluorite, quartz, calcite and barite, other nonmetallic minerals and metallic gangue minerals. Fluorite and other nonmetallic minerals occur in monomineralic bands parallel to vein walls in many places. The wider ore-lenses tend to have lower grades. There remain 9 144 000 tonnes of fluorite ore having at least 35% fluorite in the Blue Beach, Director and Tarefare vein systems.

Crystalline fluorite is more abundant in the vugs of the east-west veins. The colour of the fluorite varies within and between veins but the purple variety is more frequently seen in the wall rock breccia zones of the north-south veins. Quartz crystals also line vugs, occur as doubly terminated crystals in fluorite and locally are pseudomorphous after rhombohedral calcite crystals. Fluorite and quartz combine in a fine grained aggregate locally termed "blastonite", which is most common in the north-south veins. Calcite, more abundant in the larger veins and in the south ends of these veins, may locally exceed 10 per cent of the ore and also exceed the quartz content. It occurs in coarse white grains interbanded with fluorite and as disseminated grains and veinlets in colloform fluorite. Calcite is rarely replaced by dolomite. Barite is rarely sufficiently abundant to present a milling problem. The ore contains minor to trace amounts of metallic sulphides including in relative order of abundance galena, sphalerite, chalcopyrite and pyrite. The galena content of the fluorite ore locally reaches 15 per cent but has not been found in tonnages that would permit economic recovery.

The mineralogy, banding structures and well-preserved vugs suggest the ore is epithermal in origin and was deposited in a relatively low temperature-pressure environment. The ore solutions have been attributed to the closing, hydrothermal stage of differentiation of the St. Lawrence granite.

Replacement Deposits

No fluorite replacement deposits in carbonate rocks have been identified in Canada but such deposits in Mexico and England are a major source of fluorite. Replacement bodies occur in Lower Cretaceous limestone at the contact with Tertiary intrusive and extrusive rhyolite in the states of San Luis Potosi, Guanajuato, Coahuila, Chihuahua and Durango, Mexico (Pickard, 1974). The bodies dip outward from the rhyolite along limestone beds and are localized at the contact between the two rock types. The deposits are attributed to hydrothermal solutions which followed the rhyolite-limestone contact. In a similar setting, near Matlock, Derbyshire, England, Carboniferous limestones contain replacement fluorite bodies associated with long, steeply-dipping faults (Mason, 1974). Locally, flat lying limestones have been replaced by fluorite over considerable distances. The Masson Hill "flat", for example, extends 500 m along srike, 250 m normal to the strike and has a maximum thickness of 14 m. The mineralization was emplaced either in late Carboniferous or Permian time.

Skarn and Greisen Deposits

Skarn and greisen deposits occurring at the contacts of intermediate to felsic intrusive rocks with more than average concentrations of fluorine are widespread across Canada. Examples occur in the District of Mackenzie, Yukon Territory, British Columbia, New Brunswick, Nova Scotia and Newfoundland. Deposits and occurrences ranging from epigenetic veins to replacement bodies are present in contact aureoles or within large inclusions in granite intrusions. Some are related to swarms of granite dykes that cut marbles or schists forming thin caps overlying subjacent intrusive bodies.

District of Mackenzie, Yukon Territory. Occurrences have been reported in felsic leucocratic stocks and batholiths intrusive into sedimentary rocks in western District of Mackenzie in a belt extending southeast from MacMillan Pass (Dawson, 1977; Dawson and Dick, 1978). The best known of these, the Canada Tungsten Mine (105-12) lies on the boundary between Yukon and Northwest Territories about 150 km northeast of Watson Lake. The mine is the world's highest grade tungsten producer and the ores also contain minor fluorite (White, 1963). The ore mineral is scheelite and it is associated with variable amounts of pyrrhotite and minor chalcopyrite. The deposit is classed as a Group 1 skarn by Dawson and Dick (1978) who state, (op cit., p. 292): "W, Cu skarns, the most significant economically, are associated with an arcuate belt of small Cretaceous plutons in southeastern Yukon and southwestern Mackenzie. Host rocks are the first thick limestone beds, usually Upper Cambrian, that occur above a relatively unmetamorphosed Upper Proterozoic clastic succession."

Table 29. Bedrock formations of St. Lawrence area, Newfoundland

Era	Epoch	Period	Group or Formation	Lithology
Phanerozoic	Paleozoic	Carboniferous	St.Lawrence granite	Peralkaline alaskitic granite and rhyolite porphyry
			Intrusive contact	
		Cambrian	Inlet Group	Sandy, micaceous siltstone and quartzite
		Unconformity		
		Proterozoic	Loughlins Pond pluton	Altered, coarse grained gabbro
			Intrusive contact	
Proterozoic			Rock Harbour Group	Greywacke and shale
			Burin Group	Mafic pillow lava, mafic agglomerate and tuff
			Marystown Group	Hornfels, flow banded and spherulitic rhyolite, hornfelsed basalt flows, rhyolite flows, felsic lapilli and lithic tuff

Source – Strong et al., 1978

In addition to the Canada Tungsten Mine, six other similar fluorite-bearing occurrences are reported in southeastern Yukon Territory and near the north end of the Cassiar Batholith and the Seagull Stock (Poole et al., 1960). They include: a prospect east of Wolf Lake (105-09), the Fiddler Yukon Mine (105-05), Dorsey showing (105-04) and Seagull Creek (105-03) showings. All occur in skarns developed in Paleozoic sedimentary rocks near granite contacts. Fluorite and boron minerals occur together with quartz and other skarn minerals. Host rocks range from shales and limestones to schists, gneisses and marbles. None of these occurrences has proven economic to date.

The Fiddler Yukon property (105-05) near Mile 701.8, Alaska Highway was first staked as a tungsten prospect, although no tungsten production was achieved. Minor to trace amounts of tin and fluorine minerals were reported along with wolframite and scheelite in a collection of short en echelon veins hosted by Lower Paleozoic phyllite and limey phyllite (Poole et al., 1960; Mulligan, 1975). The veins cut the foliation of the country rocks at a low angle in the contact aureole at the north end of the Cassiar Batholith. The vertical extent of the main veins is limited, although more veins occur in the lower part of the cirque east of the main showing. Minerals associated with the wolframite include galena, sphalerite, chalcopyrite, green fluorite, scheelite and greenish mica. Secondary malachite and azurite are also present and tiny crystals of cassiterite have been identified in fractures in quartz (Mulligan, 1975). Minor pyrrhotite has also been reported from the host rocks near the veins.

British Columbia. Nearby, in northern British Columbia the Low Grade claims (104-16) on Needle Point Mountain and the Blue Light claims (104-19) contain fluorite associated with low tin values. As on the Fiddler Yukon property, mineralization occurs in skarn formed in limestone or limey shale near the north contact of the Cassiar Batholith.

New Brunswick. Fluorite is reported in granite and at the contacts of quartz-feldspar porphyry bodies at Burnt Hill (21-42) and Mt. Pleasant (21-18) properties, New Brunswick (Potter, 1970; Victor, 1957; Petruk, 1964) (Map 1588A). The first property is characterized by wolframite-molybdenite-cassiterite veins in greisenized granite and the second by irregular, ill-defined cassiterite-sulphide bodies in brecciated intrusive feldspar porphyry. Fluorite ranges in abundance from trace to near economic amounts. The Mt. Pleasant property is underlain by a felsic volcanic centre near the north side of the St. George Batholith. Here, colourless to almost black fluorite is abundant in both the mineralized greisen and the massive sulphide ore zones. Brown fluorite occurs in the tin ore and a pale variety occurs as large euhedral crystals in kaolinite masses adjacent to the ore zones. Mulligan (1975) also reported fluorite and topaz zones near Welsford, New Brunswick. These cut the rocks of the St. George Batholith and may be the same occurrences reported elsewhere as the Queens Brook (21-21) showing.

Nova Scotia. Fluorite showings related to granite contacts have been reported in the New Ross area, Nova Scotia. Here, Devonian quartz monzonite and granodiorite intrude lithic graywacke and feldspathic quartzite of the Goldenville Formation. The mineralization occurs in greisen zones in a muscovite-bearing leucogranite. Elsewhere in the area, fluorite is reported at Lower Canoe Lake (21-04) and at the Turner tin showing near Mill Road, Nova Scotia.

Newfoundland. Two fluorite occurrences have been reported in association with the contacts of granite bodies, specifically at Grey River (Mulligan, 1975) and at St. Lawrence, Newfoundland (see Fig. 28). Minor tin and tungsten minerals occur at Grey River in a quartz vein with accessory fluorite, pyrite, base metal sulphides and molybdenite. The vein cuts Ordovician(?) schist and gneiss near the contact with a pre-Carboniferous granite intrusion. The previously described St. Lawrence deposits were, until 1978, Canada's only fluorite producers (page 149). Although the main vein structures of the St. Lawrence deposits extend from the granite into the surrounding volcanic and sedimentary rocks for a few metres, economic widths of fluorite occur only in the epithermal fissure-veins within the granite host.

Unclassified Deposits

A few Canadian deposits and occurrences of fluorine are either too poorly described or lack clear evidence of origin to categorize. One example, the Rexspar uranium property has developed reserves of uranium and fluorine.

Rexspar (Birch Island)

the Rexspar property (82-51) (Fig. 29) is located 3.2 km south of Birch Island Station, 129 km north of Kamloops, on a ridge east of Foghorn Creek, north of Granite Mountain, British Columbia. A bridge across the North Thompson River connects route 5 to the forest road that leads to the property.

The claims were first located in 1918 and the property has since undergone a complicated history of exploration and ownership. Staked and explored in 1926-27 as a silver-lead property, it was then developed as a manganese property, then as a fluorite deposit and finally as a uranium-fluorite deposit. The property has been extensively drilled and reserves of 1 114 158 tonnes grading 0.773 kg/t U_3O_8 and 1 360 800 tonnes of 20 to 30% fluorite ore have been outlined.

The geology of the area was described by Campbell and Okulitch (1976) and Preto (1978). Much of the property is obscured by Pleistocene and Recent glacial deposits and alluvium. The foliated volcanic bedrocks are equivalent to the pre Late Triassic and probable Mississippian Eagle Bay Formation (Campbell and Okulitch, 1976).

According to Preto (1978) (p. 84): "In the vicinity of the Rexspar deposits, the foliated rocks are mostly of volcanic origin. Green chlorite and chlorite-sericite schist and silver-grey sericite-quartz schist of map unit 1 are the most common rock type and contain several exposures of clearly recognizable dacitic and andesitic volcanic breccia which attest to volcanic origin of a good part of these rocks. Interlayered metasedimentary members of grey phyllite and slate, quartzite, and ribbon chert are distinctly less abundant than schists of metavolcanic origin. ... In summary, therefore, map unit 3 consists of a deformed and metamorphosed pile of lithic tuff and breccia mostly of trachytic composition, but with some rhyolite members, which in the vicinity of the Rexspar deposits include coarser fragmental and probably intrusive phases. It follows therefore that the area of the mineral deposits, and particularly that between B and BD zones, probably is a volcanic centre or vent from which part or all of map unit 3 was derived."

The fluorite host rock is light grey, medium to fine grained, locally yellow stained, trachytic tuff and breccia that have been called feldspar porphyry in some descriptions. The latter contains potassium feldspar grains from 12 to 13 mm down to less than 1 mm, local clasts of grey and black chert in a matrix of smaller feldspar grains, pale green mica, scattered pyrite crystals, minor quartz and traces of molybdenite. The rocks exhibit crude bedding which is locally preserved by replacement streaks of fluorite. Disseminated pyrite is common. Fluorite has replaced beds more or less selectively in very fine-grained aggregates that contain coarser fragments of the same mineral. Near the margins of the ore zone and in lenses elsewhere, there is a black, medium to coarse grained biotitic rock that consists of biotite, pyrite, minor fluorite and rock fragments. This may be either a lamprophyre dyke or a more basic member of the tuff-breccia unit. The fluorite ore consists of fluorite, celestite, pyrite, feldspar and bastnaesite in the crudely banded tuff-breccia unit. The ore is estimated to average 10% pyrite, 20 to 30% fluorite, 15 to 25% celestite and 40 to 50% feldspar.

Structures spatially related to the fluorite ore body include colour- and grain-size banding, jointing, local brecciation and greater fissility at depth. A few minor cross faults without significant displacements have also been identified. The strike of the ore zone is N 20° to 65°E, with an average of N 35°E, and the dip varies from 20 to 60 degrees northwest. The zone has a strike length of 900 m, an average width of 38 m and a down dip extent of between 46 and 122 m.

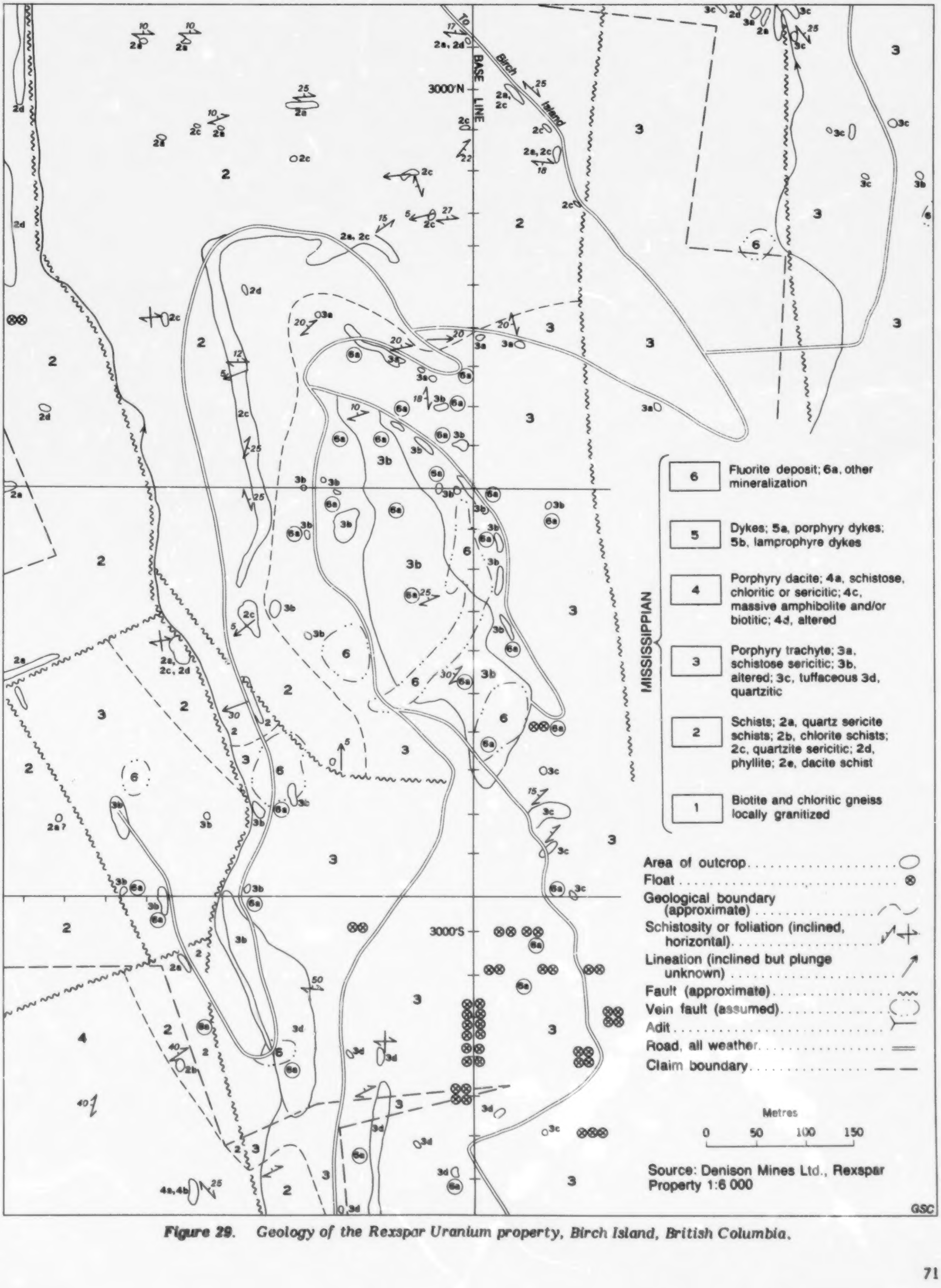
The fluorite ranges from massive fine-grained and subporcelaneous in the core of the ore zone to coarser and disseminated in the periphery of the zone. In the central part the fine grained fluorite carries scattered, coarser fluorite, disseminated pyrite, off-white celestite, scattered feldspar grains, sericite flakes and rarely galena crystals. The celestite is interstitial to the fluorite and fills fractures in the latter. Marginal to the ore zone the colour of the host rock changes to pale grey and it carries scattered feldspar grains, pyrite cubes and chert fragments embedded in a very fine grained matrix consisting of quartz, feldspar, and sericite. The weathered surfaces are rusty due to pyrite oxidation.

Summary

Barium, strontium and fluorine have been treated together in the present study because their minerals are generally associated in nature. This is illustrated in Tables 30 and 31 which show that deposits or occurrences of all three elements are common to several different deposit-types. Further examination, however, reveals some major differences in the distribution of the three elements. For example, significant deposits of barium occur mainly in syngenetic accumulations in volcanic rocks and marine shales (Table 30) but strontium minerals are entirely absent in this environment.

Syngenetic Deposits

Syngenetic deposits exhibit a great variety of associations with igneous and sedimentary rocks. For example, in igneous intrusive rocks, independent barium minerals are not abundant, and strontium minerals (mainly celestite and less commonly strontianite) are rarely primary


BASE LINE
3000'N
3000'S
Birch Island
MISSISSIPPIAN
6 Fluorite deposit; 6a, other mineralization
5 Dykes; 5a, porphyry dykes; 5b, lamprophyre dykes
4 Porphyry dacite; 4a, schistose, chloritic or sericitic; 4c, massive amphibolite and/or biotitic; 4d, altered
3 Porphyry trachyte; 3a, schistose sericitic; 3b, altered; 3c, tuffaceous 3d, quartzitic
2 Schists; 2a, quartz sericite schists; 2b, chlorite schists; 2c, quartzite sericitic; 2d, phyllite; 2e, dacite schist
1 Biotite and chloritic gneiss locally granitized
Area of outcrop
Float
Geological boundary (approximate)
Schistosity or foliation (inclined, horizontal)
Lineation (inclined but plunge unknown)
Fault (approximate)
Vein fault (assumed)
Adit
Road, all weather
Claim boundary
Metres
0
50
100
150
GSC

Source: Denison Mines Ltd., Rexspar Property 1:6 000

Figure 29. Geology of the Rexspar Uranium property, Birch Island, British Columbia.

Table 30. Summary Classification of syngenetic barium, strontium and fluorine deposits

Classes	Barium Deposit Examples	Strontium Deposits Examples	Fluorine Deposits Examples
Igneous intrusive rocks			
Basic and ultrabasic rock		Proterozoic diabase dykes and sills	
Alkaline rocks		Ben Loyal syenite, Scotland	Wahl prospect (52-96), Iron Island (31-135), Ont.; St. Michel sill (31-119), Qué.
Felsic rocks		Glenelg-Ratagan, Scotland	Whiteman Creek (82-29), B.C.; Hasbala Lake (64-1), Man.; St. Lawrence, Nfld.; Central City, Colorado; Conway, New Hampshire
Pegmatites			Crystal Mtn, Mont.; Shatford Lake (52-90), Man.; McDonald Quarry (31-87) and Cameron pegmatite (31-136), Ont.
Carbonatite and alkalic rock complexes		St. Lawrence Columbium mine (31-98), Qué.	Newman complex (31-134), Ont.; St. Honoré (22-04), Qué.; Okosuru, Namibia
Igneous extrusive rocks			
Intermediate flows and pyroclastics	Buchans (12-10), Nfld., Lynx Mine (Western Mines Ltd) (92-4), Britannia Mine (Jane) (92-6), B.C.; Kuroko deposits, Japan.		Castel Ciuliano, Italy; Rome; Oregon; Spor Mountain, Utah
Sedimentary Rocks and Clastic sediments			
Eluvial deposits	Washington County, Mo., U.S.A.; Brunswick No. 6 -sulphide deposit (21-46), N.B.	Yate, United Kingdom	Asturais, Spain; Rosiclare, Cave in Rock, Illinois
Alluvial deposits	Grand Forks (115-08), Y.T., Mile 397 (94-10), Mile 472 (94-15), Alaska Hwy., B.C.; South Newbridge (21-35), N.B.		Hunker and Germaine creeks (116-1), Y.T.; Muncho Lake (94-11), mile 397 (94-10), Alaska Hwy., Bugaboo Creek (82-40), B.C.; Tampa Bay, Florida.
Sands and gravels	Dierks, Arkansas; Guthrie, Oklahoma		
Marine shales	Tom property (105-24), Moose Group (105-21), Y.T.; Wise Claims (105-28), District of Mackenzie; Stevens Co., Washington State, Battle Mountain, Nevada; Meggen Mine, Federal Republic of Germany.		
Chemical sediments			
Carbonates	Sulphur Creek (94-13), and 110 Creek (94-10) B.C.	Cape Robert (41-02) and Manitouwaning (41-01) and Frazer Duntile quarry (31-93), Ont.; Bass Island Dolomite, Illinois	
Evaporites		Persian Gulf sabkha deposit	
Bioclastic and biochemical sediments			
Phosphorites			Lakeland, Florida
Hydrocarbons	Coal Measures, United Kingdom		
Surface waters, groundwaters and brines	Traces in river waters and ground water; hot brines; lake waters in the African rift system	Brines in U.K.; Great Salt Lake, Utah; Bristol Dry Lake, California	Brines in rift lakes, East Africa[2]; Madoc groundwaters, Ont.[1]

[1] Livingstone, 1963; Lalonde, 1973
[2] United Nations Development Program, 1973

Table 31. Summary Classification of epigenetic barium, strontium and fluorine deposits

Classification	Barium Deposit Examples	Strontium Deposit Examples	Fluorine Deposit Examples
Fissure Fillings	Brisco (82-42) and Parson (82-44), B.C.; Thunder Bay District and Yarrow Mine (41-15), Ont.; Lake Ainslie East, N.S. and Collier Cove (1-72), Nfld.	Lake Shore Gold Mine (42-4), Frontenac Lead Mine (31-9), Perry Mine (31-17), Ont.; Oka (31-98), Qué.; Dorchester (Dorbeck) (21-31), N.B.; Cheverie Cliffs (21-9) and Corney Brook (Cap Rouge) (11-59), N.S.; and Matehuaha and Torreon-Saltillo, Mexico.	Liard Crossing (94-16,-17,-21); Rock Candy Fluorite Mine (82-9) B.C.; Creswel (52-25); Silver Mtn. (52-13); Silver Islet (52-33); Perry Lake (31-16); Rogers Mine (31-21); Noyes Mine (31-12); Lee Junior (31-34); Blakely (31-13); Cardiff Uranium Mine (31-73,-75), Tripp Farm (31-79), Ont.; Lacorne Molybdenite Mine (32-7), Qué.; MacMillan (11-48), N.S.; Tarefare (1-21), Director (1-22) and Bluebeach (1-23), Nfld.; Buffalo Mine, South Africa.
Replacement Deposits	Mineral King (82-34) and Silver Giant (82-43), B.C.; Walton Mine, N.S. (21-13).	Kaiser Celestite (11-28), N.S., Gillams Cove (12-6), Nfld.	Mexico; Derbyshire, United Kingdom
Skarn and Greisen Deposits			Canada Tungsten Mine (105-12); Fiddler Yukon (15-05), Y.T.; Low Grade claims (104-16); Blue Light Claims (104-19), B.C.; Burnt Hill (21-42) and Mt. Pleasant (21-18), N.B.; Canoe Lake (21-4), N.S.
Unclassified		Wilder (31-88), Ontario	Rexspar (Birch Island) (82-51), B.C.

constituents in alkaline, felsic and carbonatite rocks (Table 30). In contrast, however, fluorine minerals (mainly fluorite and less commonly topaz and cryolite) are reported in alkaline, felsic and carbonatite igneous intrusive rocks as primary constituents. In addition, fluorine-bearing minerals such as fluorapatite (basic rocks and carbonatites) and tourmaline (pegmatites) are widespread accessory minerals. Some of these, including fluorite in pegmatite at Crystal Mountain, Montana and in the carbonatite complex at Okorusu, Southwest Africa (Namibia) have been commercial sources of the element.

Syngenetic deposits associated with igneous extrusive rocks and that are attributed to submarine volcanism and associated exhalative action, have been a commercial source of barite in Kuroko deposits of Japan. Similar deposits in Canada are a potential source of barite. For example in the Buchans Mine, Newfoundland, barite forms up to 25 per cent of the ore (p. 73). Large tonnages of low grade fluorite ore occur in lacustrine pyroclastic beds. These concentrations are also attributed to exhalative activity before the cessation of nearby volcanic activity. Deposits of the latter type have not been worked commercially for fluorite although they represent large potential sources of the element. This type is unknown in Canada at present but should be sought where lacustrine-pyroclastic sequences have been mapped.

Barium, strontium and fluorine minerals occur in a wide variety of unconsolidated and consolidated sediments. Eluvial barite has been mined for over one hundred years in a district extending from southeastern Missouri to the Atlantic coast of the United States. It is unlikely that this type of deposit will be found in Canada because of extensive glacial scour during the Pleistocene Epoch. However, in unglaciated areas in Yukon Territory and elsewhere in depressions in the bedrock surface, hidden beneath glacial till, eluvial barite may yet be discovered in Canada. Celestite is mined in Great Britiain from eluvial deposits near Yate and fluorite was mined from similar deposits at Asturias, Spain. Some eluvial fluorite was also recovered from zinc-lead-barite veins in limestone in the Tri-State District of the United States.

Unconsolidated alluvium carries barite and fluorite in a variety of occurrences in Canada and elsewhere, although none has proved commercially important. Both minerals occur in recent placer deposits in the western Cordillera of North America ranging from the western United States north to Yukon Territory. Fluorite also occurs in playa outwash fans in the western United States. Both occurrence types provide prospecting indicators to aid in the search for bedrock sources of both barite and fluorite.

Sands and gravels having diagenetic barite cement and rosettes have a limited, noncommercial distribution in the western United States. The sand or gravel beds were probably mineralized by barite almost simultaneously with the deposition of the detrital constituents.

Much baritite interbedded with shale and less commonly with limestone has been discovered in northern British Columbia, Yukon Territory and the District of Mackenzie in the last 20 years. None of these occurrences has been exploited for barite but the Tom base metal deposit at Macmillan Pass, Yukon Territory has a published reserve of more than 8 000 000 t that includes more than 2 000 000 t of barite (Carne, 1979). Doubtless others of comparable size await development and the area may be crucial to the future production of barite in western Canada. Such deposits are currently mined in Nevada and at Meggen, West Germany. Barite resources in Washington (U.S.A.), Northern British Columbia, Yukon Territory and District of Mackenzie have yet to be exploited. The common association of these bedded baritites with fine grained, clastic marine sediments is an important key to their distribution. Neither celestite nor fluorite have been recognized in this association, however, and it seems to be almost unique for barite.

Strontium is the only one of the three elements having an association with evaporates, be they ancient or modern. Sabkhas on the west side of the Persian Gulf contain primary or diagenetic celestite in recent deposits (Butler, 1973; Evans and Shearman, 1964; Evans et al., 1969); similarly celestite deposits in the Appalachian Orogen are spatially related to Carboniferous evaporate sequences. For example the celestite mined at Lake Enon, Cape Breton Island, Nova Scotia (Crowell, 1971) and the celestite resource developed on Port au Port Peninsula, western Newfoundland (McArthur, 1973, 1974).

Syngenetic barium and strontium occur in carbonate sediments at a few places in Canada. Both elements probably originally occupied intergranular interstices or were adsorbed on clay particles in the carbonate sediments. Barium content, for example, is related to the clay content of the limy sediments. During diagenesis of the unconsolidated limy sediments intergranular solutions may have dissolved the weakly-held elements and transported them elsewhere. Such solutions precipitate their barium wherever a fresh supply of the sulphate radical is encountered. The barite-calcite-sulphide veins and knots, lenses and vein fillings of celestite in the Paleozoic carbonate rocks of southern Ontario probably originated in this way.

Bioclastic and biochemical sediments are a commercial source of fluorite as a byproduct of the production of phosphate fertilizer from bedded phosphorites. The fluorine and phosphorus, accumulated from the ocean by biological processes, settle into beds on the seafloor and are further beneficiated by diagenetic processes. Barium and strontium are also accumulated biologically from both groundwater and seawater and carried into a variety of bioclastic and biochemical sediments. These anomalous concentrations of the elements are the potential sources from which vein and replacement deposits are supplied.

Hydrocarbon fuel deposits (coal, oil) locally carry anomalous amounts of barium. The element may be present in connate solutions or adsorbed on organic constituents.

Brines

Brines may seem out of place in a classification of bed rock deposits although the potential economic importance of these cannot be denied, particularly in the case of barium-rich solutions. Oilwell equipment is prematurely damaged by the deposition of barite from connate brines in California and in other oil fields. Valves are damaged and orifices plugged by barite deposition, necessitating costly replacement. Barium chloride was recovered commercially from brines flowing from Derbyshire coal measures of the United Kingdom and similarly might be recovered from barium-rich brines in some North American oil reservoirs. Anomalous amounts of strontium occur in deep well waters and playa lake brines in the Rift Lakes in Africa (U.N. Development Program, 1973) and in groundwaters at Madoc, Ontario (Lalonde, 1973) . In the latter case, the distribution in groundwater is a useful prospecting tool to aid the search for vein deposits of fluorite. Similarly, the distribution of fluorine in spring waters at St. Lawrence, Newfoundland can assist in the discovery of hidden fluorite veins (Tilsley, 1975).

Epigenetic Deposits

Epigenetic deposits of barium, strontium and fluorine are presently the main commercial source of the three elements in Canada. These deposits have been categorized as fissure fillings, replacements, skarns and greisens (see Table 31). The deposits are in a large variety of wall rocks and occupy a wide range of structures.

Fissure filling deposits of barium, strontium and fluorine minerals have been mined around the world as well as in Canada. Barite has been mined since 1946 from fissure fillings in carbonate rocks in the Brisco and Parson mines, southeastern British Columbia. Barite has also been mined at various times from fissure fillings in diabase and shales at Thunder Bay, Ontario and felsic tuffs and flows at Lake Ainslie East, Nova Scotia (1890-1925). Celestite gangue occurs in fissure fillings with metallic ores and is mined commercially from veins at Matehuala and Torreon-Saltillo, Mexico. Most Canadian fluorite production has come from fissure-filling veins: Rock Candy Mine, southern British Columbia; Madoc, Ontario and St. Lawrence, Newfoundland. The latter was Canada's main fluorite producer. Of the areas mentioned, only Lake Ainslie East properties have significant tonnages of combined barite and fluorite ore but future production will depend upon the development of an economic milling procedure.

Replacement deposits of the three elements are known in Canada and elsewhere. Canada's main barium production, until the mine closed in 1978, came from a large replacement body in limestone at Walton, Nova Scotia (Boyle, 1964). Minor production is won from the tailings at the Silver Giant and Mineral King mines, southern British Columbia, both of which are replacement deposits in dolomite and shales that were mined originally for their base metal content. Canada's main celestite production (1969-1976) came from replacement mantos in the Kaiser Celestite mine at Lake Enon, Nova Scotia. Significant resources of celestite are also present on Port au Port Peninsula, Newfoundland. Replacement deposits of fluorite are not known in Canada but have been mined in Mexico and in Derbyshire, England (Pickard, 1974; Mason, 1974). The contacts between felsic intrusions and limestone or shale are likely sites for such deposits. The fluorite-witherite deposits on the Liard Fluorite mine property, north of Liard Bridge, Alaska Highway, British Columbia are potential sources of fluorite in zones replacing brecciated shale along its contact with overlying limestone. This property is the only one known in Canada that is a potential combined source of fluorite and witherite.

Skarn and greisen deposits are more typically enriched in fluorite than in minerals of barium or strontium. The principal Canadian deposit, Canada Tungsten Mine in southwest District of Mackenzie, Northwest Territories, is mined for tungsten although the fluorite content might ultimately prove recoverable as a byproduct or coproduct. In the same general area contact metamorphism around felsic stocks has produced rare barium silicate minerals near Macmillan Pass in the Yukon Territory. In this case it is uncertain whether barium has been introduced during contact metamorphism or whether pre-existing barite veins were replaced or partially replaced by barium silicate minerals.

Unclassified deposits

Approximately 300 of the occurrences compiled in the data bank have not been classified because essential data are lacking, and others, for example the Rexspar and the Wilder, because the evidence of origin is ambiguous. Neither can be categorized as a specific type. The Rexspar deposit is related to a volcanogenic event but it is uncertain whether the wall rock is a sheared porphyry intrusion or a crystal tuff that was impregnated with fluorite and celestite by volcanic exhalations. The Rexspar deposit may produce fluorite as a coproduct of uranium mining from nearby uranium orebodies. The Wilder deposit occurs in marble wall rocks but the distribution of the celestite suggests that the deposit may represent either a broken bed or a vein. The property produced a few tons of celestite.

CONCLUSIONS

Distribution

Deposits and occurrences of Ba, Sr and F minerals are widespread across Canada. Map 1588A illustrates the geographical distribution and geological environment of 733 localities at which one or more of the three elements occur. Geographically most occurrences are in Ontario, British Columbia, Yukon, Nova Scotia and Newfoundland; there are only a few occurrences in the other provinces, with the fewest being in Saskatchewan and the Northwest Territories.

In this study, 733 deposits and occurrences have been catalogued and of these 444 are barium-bearing, 37 are strontium-bearing, and 336 are fluorine-bearing. Individual occurrences commonly contain more than one of the three elements and this results in the anomalous total (817). A total of 190 localities have reported production: of these, 40 produced barium, 8 produced strontium and 48 produced fluorine and the remaining 84 produced sulphide ores that contained one or more of the three elements in gangue minerals. The last group includes several producers and past producers that are potential future sources of barium (and less probably fluorine) from abandoned tailings ponds. Resources of the three elements appear to be sufficient for Canada's domestic requirements and to provide a surplus for export, particularly in the case of barium and strontium.

Geological Associations

Ba, Sr and F occur in several geological provinces of Canada, including the Cordilleran Orogen, the Bear, Slave, Churchill, Superior and Southern Provinces of the Canadian Shield, and the Appalachian Orogen of Eastern Canada (Douglas, 1970). Occurrences in the Cordilleran Orogen are particularly numerous near Macmillan Pass, Yukon Territory along the southwest margin of the Mackenzie Fold Belt; in the Cassiar Belt near the Yukon-British Columbia border; the Rocky Mountain Thrust Belt near Muncho Lake (Fig. 12); in the Coast Plutonic Belt; Bowser Basin; Columbia Intermontane Belt near Alice Arm (Fig. 14); in the Insular Fold Belt on Vancouver Island; in the Purcell Anticlinorium and in the Omineca Crystalline Belt near the International Boundary (Map 1588A). These occurrences are in rocks affected by the Laramide, Columbian and Nassian orogenies and less commonly in rocks imprinted by Inklinian and Tahltanian disturbances[1].

Cordilleran Orogen

Barite production from the Cordilleran Orogen is typically from veins and from tailings of abandoned base metal mines. The barite-rich tailings were produced from base metal veins and replacement deposits in the rocks of the Purcell Anticlinorium near the International Boundary. In the future, barite may be recovered from mine tailings near the boundary of the Intermontane Volcanic Belt and the Coast Plutonic Belt, near Alice Arm and in the Insular Fold Belt on Vancouver Island and from baritites interbedded with argillites and limestones in Yukon Territory and northeastern British Columbia. Celestite has not been produced from the Cordillera although it occurs in minor to trace amounts on several properties. Approximately 30 000 tonnes of fluorite was mined at the Rock Candy mine north of Grand Forks, near the United States border between 1918 and 1925. Fluorite reserves amounting to 500 000 tonnes 36.7% CaF_2 have been proven on the Tam prospect of Liard Fluorite Mines Ltd., north of the Liard Bridge on the Alaska Highway near Mile 497. Elsewhere in the Cordillera other potential sources of supply may be in tailings of such mines as the abandoned Highland Mine (82-17) and Kootenay Florence Mine (82-12) in southern British Columbia.

Bear, Slave and Churchill Provinces

A few Ba, Sr and F occurrences are present in the Bear, Slave and Churchill Provinces in the northwest part of the Precambrian Shield, in rocks deformed during the Kenoran and Hudsonian orogenies. Most known occurrences are near Port Radium and Coppermine River in Bear Province and in the East Arm Fold Belt and Nueltin Lake areas of Churchill Province.

Superior Province

The Superior Province contains a number of barium and fluorine deposits and occurrences. Barium production has been limited to the mining of a few small barite veins in the Abitibi volcanic belt. Fluorite has not been produced from the Superior Province although minor amounts occur in pegmatite dykes at the boundary between the Uchi Volcanic Belt and English River Gneiss Belt in the Bird River District of Manitoba. Fluorite also occurs with molybdenite near the Lacorne Batholith in the Québec part of the Abitibi volcanic belt.

Southern Province

The Southern Province contains many barite deposits and occurrences, mainly in the Penokean Fold Belt of Thunder Bay District (Fig. 16) and in the Cobalt Embayment. Barite veins have been mined in Thunder Bay District and the mineral is also commonly present as a gangue in silver-bearing and base metal veins of the district. The latter are usually associated with Keweenawan diabase dykes and sills and the unconformity between Archean and Proterozoic rocks. Present barite production is obtained from veins in rocks of the Cobalt Embayment. Celestite has not been reported from the Southern Province. Fluorite, on the other hand, is widespread as gangue in barite and sulphide veins but has not been produced commercially from any of these deposits.

Grenville Province

The southwestern part of the Grenville Province north of the St. Lawrence Platform in southeastern Ontario and southwestern Québec contains many deposits and occurrences of Ba, Sr and F (Fig. 22). Limited production of all three elements has been reported. Barite was mined in the Gatineau region north of the Ottawa River and occurs elsewhere as a gangue in a wide variety of veins and replacement deposits in the southern Grenville Province. Celestite was mined near Calabogie, Ontario and has been reported in fluorite veins at Madoc, Ontario (Fig. 26) and elsewhere. Fluorite was produced mainly from the Madoc area, Canada's second largest source of the mineral, and also to a limited degree from Cardiff Township, Ontario (Fig. 22).

Appalachian Orogen

The rocks of the Appalachian Orogen have yielded the principal Canadian commercial supplies of all three elements. Production has been from veins and replacement deposits mainly in the southern part of the orogen in rocks that have been affected by the Acadian and Taconic orogenies. Deposits containing one or more of the three elements occur at Hayesville, New Brunswick, in western Nova Scotia, in eastern Nova Scotia, at Belleoram, near Whitbourne, Newfoundland, in western and southeastern Newfoundland and in rocks deformed during the Taconic Orogeny along the south shore of the St. Lawrence River, Québec. Other deposits are present in rocks that were deformed and invaded by granitic plutons during the Acadian Orogeny.

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[1] Terminology used here and throughout is that of Stockwell, 1967.

Barite was produced from the Walton Mine, central Nova Scotia, Canada's former main source of the mineral (Fig. 20). This orebody occurs near the Horton-Windsor contact in the Maritime Fold Belt (Poole et al., 1969). Barite is more widely distributed than minerals of strontium and fluorine and it occurs both in monomineralic veins and replacement deposits as well as with metallic sulphides as a gangue material.

Celestite production has been from deposits associated with Carboniferous evaporites on Cape Breton Island, Nova Scotia. Reserves have been estimated for similar deposits on Port au Port Peninsula, Newfoundland. The mineral is also reported at other localities, including a significant deposit at Dorchester, New Brunswick.

Fluorite was produced from veins at St. Lawrence, Newfoundland (Fig. 28), Canada's main source of the mineral. It also occurs in greisen-skarn deposits in central and southern New Brunswick and in pegmatites in central Nova Scotia.

Lithology of Wall Rocks

Wall rock associations of Ba, Sr and F deposits may vary according to the principal element(s) present, although many deposits of all three elements occur in limestone and dolomite or their metamorphosed equivalents (marble). Barium is associated with a wider variety of sedimentary rocks than either strontium or fluorine; however it is rare in igneous intrusive rocks and in rocks affected by contact metamorphism. Stontium occurs commonly in limestone but rarely in dolomite. Fluorite occurs in granite, limestone, marble and greenstone, generally in that order of frequency, but a few fluorite deposits also occur in various other sedimentary and igneous rocks. Fluorapatite occurs in sedimentary phosphate beds.

Igneous intrusive rocks, with some exceptions, commonly carry syngenetic deposits of one or more of barium, strontium and fluorine. Syngenetic barium deposits are limited to carbonatite complexes whereas syngenetic strontium deposits occur in felsic, alkaline and carbonatite intrusions. In contrast, fluorine deposits occur in a larger variety of igneous intrusive rocks and in Canada economic amounts are found in felsic and alkaline intrusions. Canada's main production of fluorine came from epigenetic veins in alkaline rocks at Grand Forks, British Columbia and in felsic rocks at St. Lawrence, Newfoundland. Fluorapatite occurs in diabase intrusions, in carbonatite complexes, and in pegmatites and hydrothermal deposits. The carbonatite complex in Cargill Township, northern Ontario carries sufficient apatite (possibly fluorapatite) to warrant eventual production for its phosphate content.

Igneous extrusive flow and pyroclastic rocks, particularly the intermediate to felsic varieties, are common wall rocks for barium and fluorine occurrences. Many volcanogenic massive sulphide deposits contain barite as a gangue mineral as well as having associated massive barite bodies. Canadian examples of this type include the Buchans Mine, Newfoundland; Jane orebody (Britannia Mine) and Lynx Mine, British Columbia. Barite can be produced from these deposits as a byproduct of base metal production. Felsic flows and tuffs at Lake Ainslie East, Nova Scotia contain economic amounts of barite-fluorite ore in several epigenetic veins and fluorite will likely be produced from these deposits by the end of the century. One type of deposit that has not been recognized in Canada but that is known and may be commercially important elsewhere in the world consists of disseminated fluorite in lacustrine volcanogenic sediments. Examples of these occur in north-central Italy and in Oregon.

Unconsolidated eluvial sediments in Canada rarely contain ecomomic amounts of barite, celestite or fluorite. Elsewhere however barite is produced from similar deposits over a wide area in the central United States. Celestite is produced from eluvial sediments at Yate, United Kingdom and fluorite is produced from similar deposits at Asturias, Spain. Major production from this type of deposit is, however, unlikely in Canada.

Age of Wall Rocks

The wall rocks of Ba, Sr, and F deposits in Canada ranges in age from Archean to Recent. However, past producers of the three elements in Canada occur mainly in Paleozoic rocks. Examples are the St. Lawrence fluorite veins in Carboniferous granites, the Walton barite deposit in Carboniferous beds of Nova Scotia and the fluorite veins of Madoc, Ontario cutting Lower Paleozoic sedimentary rocks. The formerly productive fluorite veins north of Grand Forks, on the other hand, cut a member of the early Tertiary Coryell syenites. Future production may be won from extensive bedded baritites that are contemporaneous with the enclosing Devono-Mississippian sedimentary rocks in Selwyn Basin, Yukon Territory and western District of Mackenzie.

Mineralogy

Barium, strontium and fluorine deposits and occurrences are characterized by a variety of mineralogical associations. Barium occurs widely in the mineral barite and locally in witherite. The former commonly occurs in monomineralic veins or in association with carbonate and silicate gangue minerals. It also occurs in significant amounts with fluorite, galena, sphalerite and chalcopyrite. Other minerals least commonly associated with barite include chalcocite, tetrahedrite, gold, celestite, pyrite, bornite, limonite, calcite, strontianite, acanthite, stibnite, apatite and phlogopite. Strontium occurs in celestite, often in association with barite and less commonly with galena, sphalerite, chalcopyrite, pyrite and fluorite. Fluorine occurs in fluorite, commonly associated with one or more of barite, galena, sphalerite, chalcopyrite, pyrite and witherite. In a few F-bearing occurrences a complex variety of minerals occur, including uranothorite, celestite, uraninite, barytocalcite, mica, metatorbernite, hematite, calcite, acanthite, silver, allanite, tourmaline, feldspar, apatite and muscovite.

Geochemistry

Information on chemical associations was retrieved from the barium-strontium-fluorine data bank to test the characteristic chemical associations in Canadian occurrences. This test showed that barium was the main element in 30 past producers, five producers and 21 developed prospects (1977). Barium is associated mainly with one or more of fluorine, lead, zinc, and less commonly with copper, silver, strontium, manganese and mercury. Barium-fluorine nearly always occur together, barium-lead-zinc occur less frequently, and barium-copper-silver, barium-strontium, barium-manganese and barium-mercury combinations are least common.

Strontium was the main element in four Sr past producers and one developed prospect. The population admittedly is small but it suggests three chemical associations between barium, strontium, lead and zinc; strontium, copper and silver; and strontium and fluorine in that order of frequency.

Fluorine is present in 63 occurrences, including 43 past fluorine producers and 20 developed fluorine prospects. Fluorine is most commonly associated with barium; less commonly associated with lead, uranium, copper, zinc and strontium; and least commonly associated with silver, rare earths, lithium, iron and tungsten. These associations suggest that the chemistry of fluorine deposits is probably more complex than that of either barium or strontium in Canadian deposits and occurrences.

Structural Environments

Barite, celestite and fluorite have been produced from deposits in a number of different structural settings. Major barite production has been from replacement bodies in limestone at the intersection of faults and bedding planes and less commonly from fissure veins cutting a variety of host rocks. In the future, production will probably come from the stratiform baritites in Yukon Territory and District of Mackenzie, Northwest Territories. Celestite, on the other hand, has come from replacement mantos related to karst development, and unconformities. Most fluorite production has come from fissure veins in granite in marginal zones of batholiths and less commonly from fissure veins cutting gneisses and Paleozoic limestones. Future production will probably come from breccia zones associated with a shale-limestone unconformity such as that described on the Liard Fluorspar Mines Ltd. property north of the Alaska Highway bridge over Liard River.

Development of solution cavities and karstic surfaces often take place in thick carbonate sedimentary sequences such as those found in the western Cordillera and elsewhere. The carbonate rocks are easily dissolved by groundwater and the resulting voids may be filled by carbonates, fluorite, sulphates and minor heavy metal sulphides. Locally, the metallic sulphide content may reach economic concentrations, such as in the Mississippi-Valley type deposits of central Missouri which have been mined for barite as well as base metals (Mather, 1946). The ore consists of red clay, calcite, barite and minor galena, sphalerite and chalcopyrite. This type of geological setting has analogues in Canada where karst surfaces and caves are present in limestone beds such as in Devonian carbonates of northeastern British Columbia, in those near the south shore of Great Slave Lake, and in the Carboniferous carbonate rocks of Nova Scotia and Newfoundland. Barite and fluorite occur in such a geological setting along the Alaska Highway between Mile 397 and Mile 492. Celestite occurs in a similar environment at the Kaiser Celestite mine in Nova Scotia and on Port au Port Peninsula, Newfoundland. Celestite production from the Kaiser Celestite Mine is the only example of Canadian production from this type of deposit.

Some Ba, Sr and F deposits and occurrences, however, show no obvious structural control. These include mineral concentrations in unconsolidated regolith and stratiform concentrations in sedimentary rocks. Examples of the former include eluvial barite mined in the south-central United States celestite at Yate, England, fluorite at Asturias, Spain and, to a limited extent, Cave-in-Rock, Illinois. No Canadian examples of the eluvial type of deposits are known to date, however they may be present in protected depressions on the basement beneath glacial tills or in the unglaciated areas of the Cordilleran Orogen.

Baritites that form sedimentary units are commercial sources of barite at Battle Mountain, Nevada and at Magnet Cove, Arkansas. In Canada, they are potential sources of barite in Yukon Territory, District of Mackenzie and northeastern British Columbia. The bedded baritites are characterized by primary structures and textures typical of the sedimentary rocks in which they occur. Baritite beds vary in thickness and are interbedded with argillite, chert or limestone.

Bedded celestite is an unusual geological feature although accumulations of the mineral have been described in sulphate beds deposited by the evaporative process. For example, the mineral occurs in lacustrine sediments deposited in playa lakes and less commonly in sediments of sabkha environments as part of undeformed sedimentary sequences. These bedded deposits have not been mined but are probably the source of the celestite found nearby in veins and replacement mantos.

Ba, Sr and F are associated with contacts of felsic plutons in southwestern District of Mackenzie, Yukon Territory, British Columbia, New Brunswick, Nova Scotia and Newfoundland. The deposits and occurrences range from epigenetic veins to replacement bodies and occur either in the contact aureoles proper or within large inclusions or roof pendants in granite intrusions. A related type includes greisen and skarn deposits such as the Canada Tungsten Mine (105-12)[1] (Blusson, 1968) near the Yukon-Northwest Territories border and the Fiddler Yukon prospect (105-05) north of mile 711 on the Alaska Highway. Nearby, in northern British Columbia, the Low Grade Claims (104-16) on Needle Point Mountain and the Blue Light claims (104-19) lie near the north contact of the Cassiar batholith. Epigenetic veins carrying fluorite are also associated with granite contacts near Ainsworth in southern British Columbia. In New Brunswick fluorite is present near contacts with granite or quartz-feldspar porphyry at Burnt Hill (21-42) and Mt. Pleasant (21-18) mines. Elsewhere in the Appalachian Orogen fluorite showings are associated with granite contacts near New Ross, Nova Scotia and at Grey River and St. Lawrence, Newfoundland.

Barium, strontium and fluorine minerals all occur in fissure fillings, a number of which have been of economic significant in Canada. Barite has been produced from fissure fillings in faults in British Columbia at the Brisco Mine (82-42); in Ontario at Silver Mountain west (52-13); Cryderman (Ravena) property (42-3) in Penhorwood Township, at the Premier Langmuir barite mine (42-06) and in the Madoc area; in Nova Scotia at Lake Ainslie East; and in Newfoundland at Collier Cove. Celestite occurs in dilatant zones along faults at Third Cranberry Lake Portage, Manitoba, in the Lakeshore Gold Mine (42-04), Ontario, near Dorchester, New Brunswick and at Rear Black River, Nova Scotia. Fault zones and shear zones commonly carry fluorite and have yielded production in British Columbia (e.g. Rock Candy Mine, 82-09); Ontario (e.g. Madoc and Cardiff areas) and Newfoundland (e.g. St. Lawrence area).

Regional joint fissures are occupied by barite veins in Yarrow Township (41-15), Ontario. Where veins occur in closely-spaced swarms, local zones may prove economic to mine (e.g. Extender Minerals, Yarrow Township, Ontario). (Fig. 18A, B).

Volcanic breccia pipes which characterize many subaerial felsic volcanic centres, have been sources of fluorite both in southwestern U.S.A. and northeastern Mexico. Although this type of deposit has not been a source of fluorite in Canada, centres of felsic volcanism should be examined with this deposit type in mind.

Stockworks mineralized by barite-quartz have been described in the Beaver Mine (52-31) and at Ozone Siding (52-92) in the Thunder Bay District, Ontario. Both deposits carry some lead, zinc and copper sulphides but are not economically important.

Prospecting Methods

In addition to traditional prospecting methods barium, strontium and, particularly, fluorine are increasingly sought by geochemical and geophysical methods.

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[1] Numbers in perenthesis refer to deposit identification numbers on map 1588A (see page 8).

Traditionally, the minerals are sought in the vicinity of producing mines by a combination of normal bedrock exploration, geochemistry and diamond drilling. Target areas are customarily those in which stratigraphic and structural features resemble those known in nearby producing mines.

Geochemical Techniques

The prospecting approach is increasingly being augmented by geochemical techniques that are based on chemical analyses of rocks, lake and stream waters and sediments (Lalonde, 1973; Boyle, 1972; Shawe et al., 1976). In settled areas, well waters can be analyzed and elsewhere waters and seepages may also be analyzed with useful results. Water analyses for fluorine are made by selective fluorine ion electrode and ion analyzer techniques, whereas traditional chemical techniques are employed for strontium and barium. Waters in unmapped areas should be routinely analyzed for heavy metals and explanations sought for anomalous concentrations. These elements can travel several kilometres in solution or in suspension. Consequently the direction of water flow should be verified and man-made or natural sources of the anomaly should be sought upstream from anomalous localities.

In connection with geochemical investigations a study was made of secondary dispersion of fluorine in surface waters, stream sediments and soils near Madoc, Ontario (Lalonde, 1973). It was found that the fluorine content of the alkaline surface waters ranges from 60 to 420 ppb (parts per billion) with an average of 125 ppb. Several areas were located that showed coincident groundwater, sediment and soil anomalies. Groundwater samples taken above fluorite veins detected their presence and other anomalies may mark undiscovered veins of the mineral. In the Madoc area the fluorine content of the neutral to slightly alkaline groundwaters ranges from 21 to 1800 ppb and averages 105 ppb. The samples were collected on 1.6 km centres and the distribution of the values shows anomalies in areas of known fluorite veins and in other areas not explainable by known mineralization. The fluorine content of groundwaters collected from limestone terranes is distinctly higher than that of samples collected from the Tudor volcanic terrane in the same area. The stream sediment anomalies were spatially related to anomalies in the groundwater. The soils were sampled (A and B horizons) along two 32 km traverses. Along the first traverse the A horizon analyses yielded fluorine anomalies overlying known mineralization whereas analyses of both the A and B horizons gave anomalies on the second traverse.

Metals such as lead and zinc may be useful as pathfinder elements because of their common occurrence in fluorite veins. In the Madoc study by Lalonde (1973), zinc proved to be the most useful pathfinder element in stream sediments and waters. In another example, lead, zinc and mercury were determined in soil samples in the Asturias area of Spain with useful results. Anomalies there showed a spatial association with known fluorite veins (Friedrich and Pluger, 1971). On the other hand mercury anomalies in the Wolsendorf area of the Federal Republic of Germany were found to have no correlation with fluorite veins. Zinc anomalies in the Illinois-Kentucky district proved ambiguous because they reflect the presence of both fluorite-free zinc-lead veins and fluorite veins. Under the humid climatic conditions in Korea, heavy metals in ground water have also been used to locate fluorite veins. However, the technique has not been used with much success in the arid areas of the western United States.

Geophysical Techniques

Geophysical techniques have been applied to the search for barite, fluorite and celestite with varying degrees of success. The methods used have included radiometric, gravity, earth resistivity, refraction seismometry and VLF/EM (electromagnetic) surveys. Two radioactivity techniques are employed; direct reading with geiger or scintillation counters and induced radioactivity. The former is limited in application to veins having natural radioactive minerals associated with fluorite. Since such mineral associations are not common the technique has limited usefulness. In the case of induced radioactivity, an artificial polonium-beryllium source of radioactivity is introduced into bore-holes and determination of the induced ^{20}F radioactivity gives useful estimates of the distribution and abundance of fluorite in the wall rock. Earth resistivity has been tested and although the technique has successfully located faults; however, it has not successfully located associated fluorite veins. Refraction seismic surveys have been tried in the Illinois and Newfoundland (St. Lawrence) fluorite areas. The technique was not successful in the former area but such surveys assisted in providing data on overburden depth as well as bedrock surface contours in the St. Lawrence area. Although the survey did not directly locate fluorite veins, its use in combination with other techniques did result in the location of fluorite-mineralized faults. In the same area very low frequency (VLF) electromagnetic surveying also successfully located formerly unrecognized faults, some of which were filled with fluorite. The latter technique is equally useful in the location of water-filled and gouge-filled fissures or faults carrying argillic alteration, such as commonly occur along the walls of fluorite veins.

Soil Analyses

The search for alluvial, eluvial and bedrock deposits of the three elements is facilitated by soil analyses in areas where bedrock is obscured by glacial tills or residual soils. The method has led to the production of eluvial barite in the United States and celestite in the United Kingdom as well as to the identification of fluorite veins in bedrock at various locations around the world. Identification of the soil type is a significant factor and soil samples are recovered by a variety of pitting and drilling techniques. Glacial drift can also be useful in certain areas, as illustrated by trains of barite and fluorite vein material in drift in Nova Scotia and Newfoundland, respectively. The barite deposits in the Stewiacke, Nova Scotia area have contributed detrital barite to the drift and this can be recognized in stream beds. Fluorite veins at St. Lawrence, Newfoundland have also contributed the mineral to the glacial drift (Tilsley, 1975). Fluorite detritus was recognized in lodgment till at the base of the overburden and fluorine anomalies occur in the associated basal till and the overlying A soil horizon. Such occurrences have a spatial association with epigenetic fluorite veins and the underlying bedrock.

The persistence of fluorite, particularly in placers and lag deposits, has been used successfully to find veins of the mineral in arid regions of the western United States (Shawe et al., 1976). The mineral has been traced in stream sediments of the South Platte River for 55 km downstream from its bedrock source near Jamestown, Colorado. Similarly, dry wash sediments are known to carry clastic fluorite several km from their source. The mineral is also reported in creep deposits downslope from veins in such widely separated areas as Brown's Canyon, Colorado and

St. Lawrence, Newfoundland. Both barite and fluorite occur in modern Yukon placers and in lag gravels in steam beds in the Muncho Lake section of the Alaska Highway. The unconsolidated material is unlikely to make ore but it demonstrates the presence of the minerals in the bedrock or drift of the area. Tracing such trains upstream could lead to the source of the material.

World Outlook

Barite (barium)

The demand for barite is to a considerable extent coupled with oil exploration activity. This may result in the activation of new mines nearer the new oil exploration areas. For example oil exploration on the Alaska north slope in the Beaufort Sea and in the Canadian Arctic Islands may speed the development of the bedded baritites in Yukon Territory and District of Mackenzie.

In the future more barite will be recovered from mill tailings and waste dumps of exhausted base metal mines in the Canadian Cordillera and Appalachia.

The only foreseeable deterrent to continued development of barite mines would be the production and sale of a competitive substitute for a drilling mud and weighting agent. "Fer-O-Bar", developed and sold by Sachtleben Chemie GMBH, West Germany is available commercially. It is produced by calcining pyritic ores. However, there is skepticism regarding cost competitiveness, abrasive qualities, chemical reactivity and viscosity-suspension characteristics under all possible conditions that may be encountered.

Other technological developments will continue and these may capture a larger proportion of the current barite production. The long list of commercial uses developed in this century will also continue to support the demand for barite.

Celestite (strontium)

Celestite producers study with interest technological developments that might enlarge the existing market for the mineral. Among the most promising developments is the use of X-ray absorbing, strontium-glass face plates on colour TV tubes to minimize risk of exposure to X-radiation from the tube circuitry. European TV sets are less powerful so the electronic designers contend that a circuit modification would alleviate the problem and this may have been accomplished. American and Japanese manufacturers have been using the new tube whereas the European manufacturers have not. Consequently, the expected increase in European market did not take place. Half of the celestite imported into the United States or approximately 15 per cent of world production is used for this purpose.

A more promising development in the electronics field – the manufacture of strontium ferrite permanent magnets – has increased demand. The quality of these magnets has resulted in their use in a variety of electrical and electronic circuits. There has been an increase in the use of strontium nitrate in pyrotechnics for red, highway safety flares. A small but promising demand has developed for strontium chemicals in the production of electrolytic zinc. This technique is used in some Canadian and American smelters.

World supplies of celestite are adequate and Mexican and Spanish producers are the free world's principal source of the mineral. Great Britain stopped production at Yate, Gloucestershire in September 1974. Kaiser Celestite Ltd. shut down operations of its Cape Breton, Nova Scotia mine December 1976, because of slow market growth and failure to find a purchaser or a joint venture partner (Vagt, 1979).

Fluorite (fluorine)

The performance of the fluorite industry necessarily parallels development in the steel, chemical and aluminum industries, which together account for 95 per cent of fluorite consumption. The conversion from open hearth to basic oxygen process (BOP) for steelmaking, and vigorous growth in the chemical and aluminum industries during the 1960s accelerated fluorite consumption. The BOP steelmaking process requires three times as much fluorite as the older open hearth technology. On the other hand there is evidence of a trend to use higher grade concentrates either pelletized or briquetted to increase efficiency by reduction of dust losses. A change is being made in slag chemistry involving the partial or complete replacement of fluorite by dolomite. Both of the latter developments will tend to reduce the demand for fluorite in the steel industry.

Production of aluminum electrolytes from the fluosilicic acid byproduct of phosphate fertilizer manufacture, combined with recovery and recycling of fluorine in the alumina reduction process, will have a major effect on the world demand for fluorite. Consequently the fluorite requirements of the aluminum industry will be significantly reduced.

Demand in the chemical industry will continue to grow. Fluorine, the most electronegative of all elements, reacts with all organic and inorganic substances and thus has much potential as an industrial chemical. The controversy relating to the hypothesis that chlorine from chlorofluorocarbon aerosol propellants is responsible for the depletion of the ozone shield in the stratosphere, thus increasing the risk of skin cancer, has aroused public opinion and reduced the sale of such chemicals. An intensive search is underway to find low chlorine or chlorine-free propellants. The success or failure of this research will influence market demand for chemical grade fluorite.

Nuclear power stature will influence the demand for fluorite. Fluorine chemicals are an important reagent used in the manufacture of nuclear fuels. If increasing electricity demand results in the construction of a significant new nuclear generating capacity, this will increase the markets for fluorine chemicals.

The largest potential source of fluorine is the fluorapatite of bedded phosphate rocks that are the main feedstock of chemical fertilizer plants. In the United States alone there is a potential of 2.54 billion tonnes of fluorine from this source (Montgomery, 1974). However at the present, fluorine cannot be recovered economically from such sources except as a byproduct of fertilizer manufacture.

In summary, the outlook for fluorite is for slower growth in consumption over the next few years as a result of technological changes, public demand for lower levels of atmospheric and water contamination, and the general state of the economy. In the longer term, however, there is little doubt that the unique properties of this versatile element will result in growth in demand.

Canadian Resources

Barite

Canadian barite occurrences on record number between 300 and 400. They occur in District of Mackenzie, Yukon Territory, British Columbia, Ontario, Québec, Nova Scotia and Newfoundland. The Yukon Territory and District of Mackenzie resources are mainly stratiform deposits in the Upper Devonian – Lower Mississippian sedimentary rocks of the Mackenzie Fold Belt and the Selwyn Basin. Probably the greatest barite resource in Canada, they contain much direct shipping ore. However, transportation difficulties will delay development. The extension of Arctic drilling for oil and gas will likely influence further development and marketing of these large resources. British Columbia resources include small vein deposits (e.g. Brisco and Parson properties) and barite-rich tailings of lead-zinc mines (e.g. Mineral King with more than 250 000 tonnes and the Silver Giant) and the massive stratiform barite exposed on Sulphur Creek east of Muncho Lake. The presence of barite as a gangue mineral in sulphide ores suggests the tailings ponds for the Tulsequah Chief, Highland, Kootenay Florence and the Lynx mines should be sampled as potential future sources of the mineral. Ontario and Québec deposits are characteristically in the form of small-tonnage veins. The Walton mine in Nova Scotia is exhausted and known resources in that province are limited to the Brookfield deposit (62 000 tonnes at a grade of 50.4% $BaSO_4$) and several veins at Lake Ainslie East which have combined reserves of 4 000 000 tonnes at 28.68 to 71.14% $BaSO_4$ (Felderhof, 1979; Zurowski, 1972). Production from the latter deposit is awaiting development of a milling technique to separate fluorite and barite. The Buchans, Newfoundland massive sulphide deposit contained 25% barite and, consequently, tailings (more than 250 000 tonnes with 40% $BaSO_4$) which have been ponded since 1968 are a significant resource of partly-milled barite (McArthur, 1973, 1974). Barite production from these sources began in August 1981.

Celestite

Canadian celestite deposits and occurrences on record number 36 and they are all small. They occur in central British Columbia, Nova Scotia and Newfoundland. The fluorite orebody on the Consolidated Rexspar Uranium property, British Columbia is a potential source of celestite as a by-product of fluorite production. The Kaiser Celestite mine at Lake Enon, Nova Scotia, although it was a major producer of the mineral for several years, closed in 1976 due to market decline. A total of 40 000 tonnes of celestite ore remains in a stockpile and 950 000 tonnes of 60-65% $SrSO_4$ is still in place (Felderhof, 1978). Small deposits are known on Port au Port Peninsula, Newfoundland including the Gillams Cove (18 000 tonnes) and Ronan (152 000 tonnes of mixed barite-celestite) bodies (McArthur, 1973). The world production of celestite in 1981 was 40907 tonnes (United States, Bureau of Mines, 1979), consequently published Canadian reserves for Port au Port Peninsula and Lake Enon (Kaiser Celestite) would represent 30 years world supply barring a major war that would produce a sharp increase in demand for the mineral. Large reserves of celestite are currently unknown and future production from presently known small deposits depends on low production costs and proximity to world markets.

Fluorite

Canadian fluorite deposits and occurrences on record number more than 200, a few of which constitute significant resources. Occurrences of potential value are in British Columbia, Nova Scotia and Newfoundland. The Rexspar property in central British Columbia has reserves of fluorite ore (1 000 000 tonnes at a grade of 29% CaF_2) that may be recovered as a byproduct of uranium mining (Northern Miner, Aug. 9, 1973). The Tam fluorite-witherite body at Liard Crossing, northeastern British Columbia has more than 500 000 tonnes of 36.7% CaF_2 and potential for the discovery of additional ore (Woodcock and Smitheringale, 1957). The Rock Candy mine, north of Grand Forks, British Columbia still has a few thousand tonnes of ore in place. Fluorite resources remain in the Madoc, Ontario area but high mining costs make early development unlikely (Guillet, 1964). Several vein deposits at Lake Ainslie East, Nova Scotia have combined reserves that exceed 4 000 000 tonnes of 7.02 to 23.23% CaF_2 and these may be mined when milling problems are resolved (Felderhof, 1978). ALCAN closed its fluorspar mines at St. Lawrence, Newfoundland in 1978, although a substantial resource of fluorite remains in the mines (9 144 000 tonnes at 35% CaF_2). The development of one or more of the properties noted here awaits improvements in market conditions. Pearce (1977) reported that (p. 2-3): "Fluorine is being recovered as fluorsilicic acid from the processing of phosphate rock by ERCO Industries Limited (Formerly Electric Reduction Company of Canada Ltd.) at Port Maitland, Ontario and by COMINCO Ltd. at Trail, British Columbia."

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APPENDIX A

Appendix A describes the computer data bank developed to facilitate study of barium, strontium and fluorine deposits in Canada. It includes a general description of the file (see below) and the coding manual. Originally, the data bank was processed by means of MARS VI[1] Data Management System available on the E.M.&R. Cyber 74 computer but was later converted to the IS/ATHENA system.

Each record consists of information related to one of 733 deposits and occurrences across Canada. The individual record consists of one, 80-column card and thirteen 59-column cards combined, having a common (17 character) header consisting of the accession number, province or territory code, three commodity codes and the development code (see general file definition). Two additional subitems (TKPROV = tectonic province and SUBPROV = tectonic subprovince) have been attached to the end of the last subrecord. Individual records range up to 3607 characters long and have up to nine replicate subrecord entries (see below).

The coding manual for the data bank which is reproduced on the following pages is subdivided into card-images as presented in the general file definition. Each subitem is identified by the code name, the abbreviated name, the size and nature of the entry and by a brief description.

General File Definition

Card		Card Columns	Replicates
1.	Site IDENTIFICATION	1 - 76	
2.	GEOLOK(location card)	77 - 312	4
3.	ORE(ore minerals)	313 - 548	4
4.	GANG(gangue minerals)	549 - 666	2
5.	PRODRES(production reserves data)	667 - 902	4
6.	OREBODY(description of orebody)	903 - 1138	4
7.	WALL-ROCK(description of wall-rocks)	1139 - 1374	4
8.	STRATAGE(stratigraphy)	1375 - 1610	4
9.	DEVMNT(property development)	1611 - 1846	4
10.	GEOPHY(geophysical surveys)	1847 - 2082	4
11.	COMPNAME(company name)	2083 - 2613	9
12.	REFLIST(bibliography)	2614 - 3144	9
13.	ATUDE(attitude of orebody)	3145 - 3262	2
14.	NOTES(comments on site)	3263 - 3557	5
	TKPROV(name of tectonic province)	3558 - 3582	
	SUBPROV(name of tectonic subprovince)	3583 - 3607	

IDENTIFICATION CARD NO. 1

ACNO ACCESSION NUMBER 5ch NUMERIC

The accession number (ACNO) is assigned in a single sequence, having some gaps, from 6408 to 8241. The numbers are assigned to each deposit and occurrence, with separate orebodies in a large mine in some cases numbered indiidually.

PROVCOD PROVINCE CODE 2ch. NUMERIC

PROVCOD is a short numeric values list that is interpreted automatically as two to four letter abbreviations commonly used to identify the Canadian political provinces and territories.

COMM1 - 3 COMMODITY1 - 3 3ch. ALPHABETIC

These three fields identify the principal elements produced or reported at the mineralized locations identified in the DATABANK. These include the two-character chemical symbols and three-character codes for mineral products such as biotite or feldspar.

DEVCOD DEVELOPMENT CODE 1ch. ALPHABETIC

This code records the state of development or exploitation of a property. The code is a values list 6-items long.

1. past producer
2. producer
3. developed prospect
4. prospect
5. showing
6. subshowing

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[1] MARS = multiple access retrieval system

For items 1 and 2 see introduction to Appendix A. Developed prospects have had surface, subsurface, diamond drilling and/or geophysical work completed and a reserve has been calculated. Prospects are classed as mineralization-bearing properties on which development has been undertaken in three dimensions; showings have been developed in two dimensions and subshowings are simply mineral occurrences.

DVLPM DEVELOP CODE 1ch. NUMERIC

This subitem redefines the preceding code in numeric terms to permit mathematical treatment of the codes in the field. For example these codes are used to generate symbols printed on index maps.

ACCESS FILE ACCESS 1ch. ALPHABETIC

This subitem is used to identify the few records that are not in the public domain. The letter C in this field indicates the record contains classified material.

FLDNO FIELD NUMBER 8ch. ALPHABETIC

This field was designed for numbers applied to specimens collected as the result of field work. The subitem was not used.

PROJNO PROJECT NUMBER 6ch. NUMERIC

This 6-digit number is the project identifier assigned to official projects funded by the G.S.C. The left two digits identify the decade and year of commencement. The last two or three identify the project within the year.

ENTDAT ENTRY DATE 4ch. NUMERIC

This field contains the date on which an entry was made into the file. The month and year are coded by two digits each.

COMPLR COMPILER INITIALS 3ch. ALPHABETIC

The last individual to make additions to or modifications to the record are identified by three initials in this field.

REVDAT REVISION DATE 4ch. NUMERIC

The last date of record revision are coded in this field by decade and year.

NAME OREBODY NAME 26ch. ALPHABETIC

The name of the mineralized location commonly adopted from the most recent literature reference, less commonly improvised from the township in which the location occurs and rarely from a nearby geographical place name.

UTMZO UTM ZONE 2ch. NUMERIC

This field contains a two digit series of numbers that relate to the Universal Transverse Mercator decimal scheme that generates geographical coordinates. The zones are uniformly 6 degrees of longitude and they are numbered by a two-digit sequence that decreases from 200 to 07 across the land mass of Canada. These form part of the geographical location of the individual records.

OBJLOC OBJECT LOCATED 1ch. ALPHABETIC

The subitem includes a values list that identifies a few classes of mineralized locations. In cases other than nos. 1 and 2, the location given is the centroid of the claim, of or mineralization.

1. mine shaft
2. pit
3. claim
5. lot
6. showing

OBJECT OBJ LOCATED 1ch. NUMERIC

The subitem interprets the contents of the preceding subitem field as numeric permitting mathematical manipulations of its contents.

DISYR DISCOVERY YEAR 2ch. NUMERIC

This field contains the date consisting of decade and year in which the mineralization was first reported.

GEOLOK LOCATION CARD NO. 2

The geographical location card has a potential of 4 replicates to record geographical information related to the mineralization.

GEOLOC1 DISTRICT OR COUNTY 19ch. ALPHABETIC

The field contain a description of the land survey units that contain the mineralized location and this relates to relatively large areas like mining districts or counties. Hastings County, Ontario or Burin Peninsula, Newfoundland are examples.

GEOLOC2 TOWNSHIP ETC 19ch. ALPHABETIC

A total of 19 characters used to name the township in which the mineralization occurs or a geographical note describing the location in terms of nearby named geographical features. Cardiff Township, Ontario or 3 mi. w. St. Lawrence are typical examples.

UNCERLOC UNCERTAINTY OF LOCATION 1ch. ALPHABETIC

Single character entries forming a values list identify the scale of the source map.

1. 12000
2. 15840
3. 31680
4. 50000
5. 63360
6. 126720
7. 250000
8. 500000
9. 1000000

LATT LATITUDE 6ch. NUMERIC

The latitude of the location is coded in degrees(2), minutes(2) and seconds(2).

LONG LONGITUDE 7ch. NUMERIC

The longitude of the location is coded in degrees(3), minutes(2) and seconds(2).

NTSNO PRIME SQUARE 3ch. NUMERIC

This three digit number is the first part of the code number used to identify topographic or other maps produced by the Canadian Government. It consists of three digits ranging from 001 to more than 300. The number is right justified and lead zeros are always inserted.

SUBNO SECONDARY SQUARE 4ch. ALPHABETICAL

The SUBNO code consists from left to right of a single letter sequence – A to P, a two digit sequence 01 to 16 and a single letter code E or W to identify east and west half map-sheets.

ORE CARD NO. 3

The ore description card has a potential of 4 replicates. The elements and ore minerals have been coded in this field. The gangue minerals are also coded in this field.

ELMNT1 - 7 ELEMENT 1 - 7 3ch. ALPHABETICAL

List of the elements present in the mineralization in approximate order of abundance. The entries consist mainly of left justified chemical symbols and rarely abbreviated mineral names like mica or quartz or feldspar.

MIN1 - MIN6 MINERAL 1 to MINERAL 6 4ch. ALPHABETICAL

Six mineral species can be coded using 4-letter mnemonics. They may be sequenced in order of abundance.

MINCD1 - MINCD6 MINERAL CODE 1 to 6 2ch. ALPHABETICAL

When used these codes indicate the order of abundance of the minerals in the property.

FILLERE FILLER 1ch

VEINPOS POSITION VEINS 1ch. ALPHABETICAL

This field is used to code the position of the mineralization in the structure or body. The field was rarely filled.

1. centre
2. walls.
3. other

GANG NO. 4

These cards (2 replicates) list nine gangue minerals coded as four-letter mnemonics coupled with an abundance code. They also contain entries for isotope analyses.

MINRL1 - 9 GANG MIN 4ch. ALPHABETICAL

Four-letter mnemonics are used to name the gangue minerals reported.

MNLCD1 - 9 GANG COD 1ch. ALPHABETICAL

Single digit code intended to rank the minerals in order of abundance. Field unused.

ISOTOP ISOTOPE ANAL 2ch. ALPHABETICAL

This field was used to indicate such analyses and the type done.

01 = sulphur, 02 = Pb.

ANAL1 - 2 ANALYSIS REF1 - 2 6ch. ALPHABETICAL

Not used.

PRODRES CARD NO. 5

These cards (4 replicates) report the production and reserves data for individual locations. Other data included are references and the classification scheme for Ba, Sr and F deposits and occurrences.

PROD PRODUCT 000 6ch. NUMERIC

This field contains production information for one commodity per card image and four commodities per record.

UNIT PRODUCTION UNIT 1ch. NUMERIC

Code for the units used for production figures. 1. short tons, 2. pounds and 3. ounces.

CHEMEL CHEMICAL CODE 2ch. ALPHABETIC

Element identifier for element production. Chemical element codes used and, rarely, codes for non-metallic mineral commodities.

YR1 FROM YR. 2ch. NUMERICAL

Production period limit commencing year.

YR2 TO YR. 2ch. NUMERIC

Production period limit terminating year.

RESCOD RESERVES CODE 1ch. ALPHABETICAL

The characteristics of the reserves data are coded in this field.

1. reserves
2. other published figures
3. estimate
4. tons/vertical foot
5. average from measured section
6. one measured section
7. grab sample

TONS RESERVES TONS 6ch. ALPHABETICAL

Published figures.

DATPUB DATE PUBLISHED 2ch. ALPHABETICAL

Date production or reserves figures published. Decade and year are coded.

METHOD1 - 4 ANALYTICAL METHOD 1ch. ALPHABETICAL

Field contains coded identification of analytical method to obtain compositional data. 1. assay, 2. chemical analysis, 3. spectrographic analysis.

REF1 - 4 REFERENCE1 - 4 7ch. ALPHABETICAL

Brief reference to source of the rock or mineral analyses.

SYNCLAS SYNGENETIC DEPOSITS 4ch. ALPHABETICAL

Table of values for classification scheme for Ba, Sr and F mineral deposits based on their wallrock lithology.

1110. mafic, ultramafic rocks
1120. alkaline rocks
1130. felsic rocks
1140. pegmatite
1150. carbonatite
1220. intermediate extrusive rocks
1311. residual eluvial
1312. transported alluvial rocks
1313. marine shales
1320. brine
1322. evaporites
1323. carbonate
1331. black shale
1332. hydrocarbon
1340. others
1440. regionally metamorphosed rocks

EPICLAS EPIGENETIC DEPOSITS 4ch. ALPHABETICAL

Epigenetic part of the deposit classification scheme.

2100. FISSURE FILLINGS
2111. ultramafic rocks
2112. alkaline rocks
2113. felsic rocks
2114. pegmatites
2115. carbonatites
2121. mafic volcanic rocks
2122. intermediate volcanic rx.
2123. felsic volcanic rocks
2131. sand, sandstone
2132. shale, argillite
2141. limestone, dolomite
2142. iron formation
2151. skarns
2152. in regionally metamorphosed rocks.
2200. REPLACEMENTS
2210. intrusive rocks
2220. volcanic rocks
2231. sandstone
2232. shale
2241. limestone
2242. evaporite
2300. INDETERMINATE
2310. intrusive rocks
2320. volcanic rocks
2330. clastic sediments
2340. chemical sediments
2350. metamorphic rocks

OREBODY CARD NO. 6

Description of the barium, strontium and fluorine deposits and occurrences in Canada.

FORM OREBODY FORM 2ch. ALPHABETICAL

General shape of the mineralized bodies.

1. lens
2. sheet
3. vein
4. bed
5. pocket
6. dripstone
7. stockwork
8. indeterminate

ATTIT OREBODY ATTITUDE 1ch. ALPHABETICAL

1. discordant
2. concordant
3. concordant-discordant
4. indeterminate.

SIZE OREBODY SIZE 1ch. ALPHABETICAL

Maximum tonnage of the mineralized body.

1. 0-1000T
2. 1000 - 20000T
3. 20000 - 200000T
4. +200000T

LENGTH LENGTH x10FT. 4ch. NUMERIC

FORMW MAXIMUM WIDTH FT 4ch. NUMERIC

TOW MINIMUM WIDTH FT 3ch. NUMERIC

DEPTH DEPTH x10FT 3ch. NUMERIC

FILLERL (Unused space) 6ch.

ORESTR1 - 2 ORESTRUCTURES 1ch. ALPHA

ORESTRUCTURES subitem provides an opportunity to describe the dominant structures or textures observed in the ore itself.

1. massive
2. disseminated
3. bands
4. breccia
5. nodules
6. oolites
7. massive-bands
8. crystalline
9. colloform

HOSTSTR1 to 2 ORE-BEARING STRUCTURES 1ch. ALPHABETICAL

HOSTSTR subitem is a brief description of the structure in which the mineralization is reported. Single words are used when they apply to a given situation.

1. strata
2. reefs
3. breccia
4. fissures
5. fault
6. contact

MACROSTR MACROSTRUCTURE 24ch. ALPHABETICAL

This subitem provides space in which to identify named large regional structures in the vicinity of the mineralization. For example the Rocky Mountain Trench or the Forcier Fault might appropriately be named in two cases.

UNSERLOK LOCATION UNCERTAINTY 5ch. NUMERIC

UNSERLOK subitem provides a measure of the precision of the geographical location of the mineralization.

SEQNO SEQUENCE NUMBER 3ch. NUMERIC

The SEQNO is a simple sequence of three digit numbers for deposits and occurrences within each lettered NTS quadrangle. The zero point for the sequence number is the south west corner of the quadrangle. The numbers increase northward and eastward within the quadrangle. These numbers are combined with the NTS number to give the identification numbers used in the text and the figures of the report.

WALLRX CARD NO. 7

These cards (four replicates) contain descriptions for five different wall rocks of the mineralized body. Values lists permit coding a list of detailed parameters.

ROCK1 - 5 WALL ROCK 1 - 5 4ch. ALPHABETICAL

The entry in the field is a four-letter mnemonic name for the wall rock.

SED1 - 5 SEDIMENTS1 1ch. ALPHABETICAL

1. unspecified
2. clastic
3. carbonate
4. other

IGNRX1 - 5 IGNEOUS ROCK 1 - 5 4ch. ALPHABETICAL

1. unspecified
2. intrusive
3. extrusive
4. pyroclastic

METRX1 - 5 METAMORPHIC RX 1 - 5 4ch. ALPHABETICAL

1. unspecified
2. low grade
3. medium grade
4. high grade

RLORE1 - 5 RELATION TO ORE1 - 5 1ch. ALPHABETICAL

1. ore itself
2. contains ore
3. adjacent to ore
4. cuts ore

ALTER1 - 5 WALL ROCK ALTERATION1 - 5 2ch. ALPHABETICAL

1. chloritization
2. dolomitization
3. silicification
4. argillic
5. alunitization
6. carbonatization
7. sericitization

FILLS FILLER 9ch.

STRATAGE CARD NO. 8

This card (four replicates) treats the age of the wall rocks.

FMNAM FORMATION NAME 20ch. ALPHABETICAL

Formation names of the wall rocks are spelled out as completely as space permits. When too long they are truncated on the right end.

SEDD DOM SED CHAR 1ch. ALPHABETICAL

The subitem codes the dominantly sedimentary characteristics of the wall rock.

1. unspecified
2. clastic
3. carbonate
4. other

IGND DOM IGN CHAR 1ch. ALPHABETICAL

This subitem codes the dominant igneous characteristics of the wall rock.

1. unspecified
2. intrusive
3. extrusive
4. pyroclastic

METAD DOM META CHAR 1ch. ALPHABETICAL

This subitem codes the dominant metamorphic characteristics of the wall rock.

1. unspecified
2. low grade
3. medium grade
4. high grade

SEDS SUB SED CHAR. 1ch. ALPHABETICAL

The subordinate sedimentary characteristics of the wall rock are coded in this field.

1. unspecified
2. clastic
3. carbonate
4. other

IGNS SUB IGN CHAR 1ch. ALPHABETICAL

The subordinate igneous characteristics of the wall rock are coded by this subitem.

1. unspecified
2. intrusive
3. extrusive
4. pyroclastic

METS SUB META CHAR 1ch. ALPHABETICAL

The subordinate metamorphic characteristics of the wall rock are coded in this field.

1. unspecified
2. low grade
3. medium grade
4. high grade

LIMCOD LIMIT CODE 1ch. ALPHABETICAL

LIMCOD subitem treats the limits of the stratigraphic ages of the wall rocks.

1. Exact age (SPECIFIC AGE)
2. (FROM) minimum age
3. (PRE) maximum age

EON1 1ch. ALPHABETICAL

The subitem consists of a short values list.

1. Phanerozoic
2. Proterozoic
3. Archean

ERA1 - 2 1ch. ALPHABETICAL

Subitem ERA is used to record the stratigraphic era names where available.

1. Cenozoic
2. Mesozoic
3. Paleozoic
4. Hadrynian
5. Helikian
6. Aphebian

PERIOD1 - 2 PERIOD INTERVAL 2ch. ALPHABETIC

Subitem Period is used to record the stratigraphic period names where these have been reported.

01. Quaternary
02. Tertiary
03. Cretaceous
04. Jurassic
05. Triassic
06. Permian
07. Carboniferous
08. Pennsylvanian
09. Mississippian
10. Devonian
11. Silurian
12. Ordovician
13. Cambrian

EPOCH1 - 2 PHANEROZOIC EPOCH 1 2ch. ALPHABETIC

Subitem EPOCH provides an opportunity to code the names of the Phanerozoic epochs.

01. Pleistocene
02. Pliocene
03. Miocene
04. Oligocene
05. Eocene
06. Palaeocene
07. Upper
08. Middle
09. Lower

FILL4 SPACE FILLER 19ch.

DEVMNT CARD NO. 9

This card (four-replicates) records some details on the exploration and development of the properties in question.

MAPT MAP TYPE 1ch. ALPHABETICAL

MAPT is used to code three types of maps.

a. airborne survey
s. surface
u. underground

FRACT MAP SCALE FRACTION 7ch. NUMERIC

FRACT subitem is used to compile the second part of the map scale fraction.

FILLERR SPACE FILLER 1ch.

YEAR2 PUBLICATION YR 2ch. NUMERIC

YEAR2 subitem records the decade and year in which the source map was published.

STRIP STRIPPING DONE 1ch. ALPHABETICAL

STRIP records the existence of surface stripping at the mineralized site.

STRAR AREA STRIPPED x000 3ch. NUMERIC

STRAR codes the area stripped in square feet.

TREN TRENCHING DONE 1ch. NUMERIC

TREN contains a code indicating the existence of surface trenching.

TRENLN LINEAL FT TRENCHING x 0 4ch. NUMERIC

TRENLN subitem permits coding of the linear feet of trenching reported on the property.

OPPIT OPEN PIT DONE 1ch. ALPHABETICAL

OPPIT subitem indicates whether or not open pitting was done.

OPPITL PIT LENGTH x 10 FT 3ch. NUMERIC

This field contains the maximum length of reported open pit on the property in question.

OPPITW PIT WIDTH x 10 FT 3ch. NUMERIC

This field contains the maximum width of open pit reported on the property.

OPPITD PIT DEPTH x 10 FT 3ch. NUMERIC

This field contains the depth in feet of open pit reported on the property.

UNDRGND UNDERGROUND DEV DONE 1ch. ALPHABETIC

This field indicates whether or not underground development was reported.

1 = yes.

SHAFT SHAFT DEPTH FT 4ch. NUMERIC

DRIFT DRIFT LINEAL FT 4ch. NUMERIC

CROSC CROSSCUT LINEAL FT 4ch. NUMERIC

RAIS RAISE LINEAL FT 4ch. NUMERIC

ADIT ADIT LINEAL FT 4ch. NUMERIC

DDH	D-DRILLING DONE	1ch.	ALPHABETIC

1 = yes

SLFT	SURFACE LINEAL x 1000 FT (diamond drilling)	3ch.	NUMERIC
ULFT	UNDERGROUND LINEAL 1000 FT (diamond drilling)	4ch.	NUMERIC

GEOPHY CARD NO. 10

This card (four-replicates) was planned to file information about geophysical surveys reported on the property. The card was not used. Card columns 1847-2082 are vacant.

COMPNAME CARD NO. 11

This card was designed to outline the corporate history reported for the property (nine-replicates).

OPDATF	OPERATED FROM	2ch.	ALPHABETICAL

Property was a producing mine from this date reported as decade and year.

OPDATT	OPERATED TO	2ch.	ALPHABETICAL

Property ceased production on this date reported in decade and year.

CONAM	COMPANY NAME	29ch.	ALPHABETICAL

The corporate name of the operating company is recorded in this field and depending upon length it is or is not truncated at the right end.

FILL7	SPACE FILLER	26ch.	

REFLST CARD NO. 12

REFLST or reference list card (nine-replicates) consists of publication date, author(s) name and pagination of the source report.

YEAR	YEAR PUBLISHED	4ch.	ALPHABETICAL
AUTHR	AUTHORS NAME(S), PAGES	30chs.	ALPHABETICAL
FILL8	SPACE FILLER	15chs.	

ATUDE CARD NO. 13

This card (2-replicates) files the attitudes of three veins for the property.

VENO1,-2,- 3	VEIN NUMBER 1,-2,- 3	1ch.	ALPHABETICAL
AZ1,-2,- 3	AZIMUTH 1,-2,- 3	3ch.	NUMERICAL
DIP1,-2,- 3	VEIN DIP 1,-2,- 3	2ch.	NUMERICAL
DIR1,-2,- 3	DIRECTION 1,-2,- 3	2ch.	ALPHABETICAL
FILL9	SPACE FILLER	17ch.	

NOTES CARD NO. 14

Card (five-replicates) filled free-form with information not coded elsewhere in the individual records.

NOTES	COMMENTS	59ch.	ALPHABETICAL

ADDITIONAL SUBITEMS – NOT CARD IMAGES

TKPROV	TECTONIC PROVINCE	25 ch.	ALPHABETICAL
SUBPROV	TECT SUBPROVINCE	25ch.	ALPHABETICAL

APPENDIX B

Barium

Appendix B contains descriptive notes on the principal Ba, Sr and F minerals and brief lists of their occurrences. This information is considered to be supplementary to and in support of Tables 10, 11 and 12.

BARITE($BaSO_4$)(Deer, Howie and Zussman, 1967, pp. 189-195) is the most common barium mineral and the most widespread. It is a member of the barite mineral group that includes celestite and anglesite. Barite in some cases occurs in oriented growths with anglesite, witherite, barytocalcite and calcite. The mineral is pigmented by inclusions of hematite, sulphides, amorphous carbon, clay and petroleum. The distribution of the included material may cause zoned bands. In some cases mineral contains hydrogen sulphide and this may cause a foetid odour when a specimen is struck.

Barite occurs in moderate to low temperature hydrothermal metalliferous veins; filling solution cavities in carbonate rocks; in deeply weathered soils overlying baritiferous carbonate rocks; in hematite deposits; with manganese minerals in marine or lacustrine deposits; in barite roses in poorly consolidated sediments or soils; and in sequences of interbedded barite, chert and argillite. Barite occurs at numerous sites around the world and consequently a selection of examples will be limited to Canada and the United States. Silver veins carry barite gangue at Thunder Bay, Ontario. Solution cavities in Devonian limestones of northeastern British Columbia are locally mineralized by barite. Residual deposits are best illustrated by deposits in Missouri, U.S.A. and perhaps less well by the barite in the gossan overlying Brunswick No. 6 orebody (21-46), Bathurst, New Brunswick. Barite is associated with iron formation beds at Austin Brook (21-47), New Brunswick. Barite rosettes have been reported in weakly consolidated sandstone in the Dierks District, Arkansas, and Paul's Valley in Oklahoma. Probably the largest barite deposits in the world are the baritites at Battle Mountain, Nevada and near Macmillan Pass, Yukon. Massive barite also occurs in volcanogenic massive sulphide deposits in the Buchans, Newfoundland (12-10) base metal mine.

WITHERITE ($BaCO_3$)(Deer, Howie and Zussman, 1967, pp. 319-322) is the most common barium mineral after barite. Ca, Sr and Mg sometimes substitute for Ba in amounts less than 1 per cent. A complete series with $SrCO_3$ and a partial series Ca:Ba = 1:2 have been synthesized. Witherite occurs mainly in low temperature veins, nearly always in sedimentary rocks with galena, anglesite, alstonite, barytocalcite and barite. It ranges in abundance from the main constituent to a rare or gangue mineral.

Witherite has been reported in a few Canadian sites including the silver vein of the old Porcupine Mine (52-25), Thunder Bay District, Ontario and in several showings including the GEM claims (94-15) north of Mile 498, Alaska Highway. The mineral has been reported at Leogang, Salzburg and Peggau, Styria, Austria; at Pribram, Bohemia; Chateau Thinières, Beaulieu, Cantal and Brioude, Haute Loire, France; Freiberg and Andreasberg, Saxony in Germany. Commercial production was obtained in northern England from witherite, barite, calcite and galena veins. These sites include; Alston Moor, Cumberland, Fairstones and Fallowfield, Northumberland and Annfield Plain, Durham (Collins, 1972). Witherite is reported in Tsubaki Silver Mines, Honshu, Japan (Dana, 1932); North Caucasus and Kopets Mountains, Karakala Region, Turkmenia, U.S.S.R., barite veins at Lexington, Kentucky; Glacier National Park, Montana; Rosiclare, Illinois; Mariposa and Shasta Counties, California; and, Yuma County, Arizona, U.S.A.

BARYTOCALCITE ($CaBa(CO_3)_2$), (Deer, Howie and Zussman, 1967, p. 188) is a carbonate of calcium and barium that is dimorphous with alstonite. Barytocalcite alters to barite and pseudomorphs of barite and quartz have been found after the mineral. Crystals of the mineral are found to two inches long and cleavable masses with barite, calcite and fluorite are present in veins at Alston Moor, Cumberland, England (Collins, 1972). Quartz pseudomorphs are reported from Mies, Bohemia and Badenweiler, Freiberg, Saxony. It has also been reported from Langban, Sweden with the mineral hausmannite. Barytocalcite has been reported from the Fire prospect (94-18) north of mile 498, Alaska Highway, British Columbia and the Kingdon Lead Mine(31-94), Ontario.

GILLESPITE ($FeO.BaO.4SiO_2$) (Dana, 1932) is an iron-barium silicate reported in a rock specimen from a moraine near the head of Dry Delta, Alaska Range, Alaska. It is also found in a contact metamorphosed barium vein on the Clyde Smith claims(105-19) south of Macmillan Pass (Montgomery, 1960).

PSILOMELANE ($BaMn^{2+}Mn^{4+}{}_8O_{16}(OH)_4$) (Dana, 1951) is a basic oxide of barium and manganese having Ba^{2+}:Mn^{2+} = 1:1. Small amounts of Cu, Co, Ni, Mg, Ca, W and alkalis are often present either adsorbed, mechanically mixed or substituting for Ba and/or Mn. Psilomelane is a secondary mineral formed at surface conditions of temperature and pressure and is associated with pyrolusite, goethite, limonite, hausmannite, chalcophanite and braunite. It is a common weathering product of manganiferous carbonates or silicates, forming residual deposits or impregnations, and also occurs as bedded accumulations in lakes and swamps, replacement deposits in limestone or dolomite and occasionally as a hypogene hydrothermal product. Psilomelane occurrences may be masked by mixtures of hydrated manganese oxides containing little or no barium.

Psilomelane occurs in the Markhamville manganese mine (21-22) in southern New Brunswick. It was originally described at several sites in Europe; Saxony and Thuringia, Germany; Romanèche-Thorins, France; Ottrez, Belgium; Orkney Islands, Scotland; and Skidberg, Sweden (Dana, 1951). Other occurrences are reported at Tekrasai, Central Provinces, India; Virginia and Arizona, U.S.A.

HARMOTOME $(K_2Ba)Al_2Si_5O_{14}.5H_2O$ (Dana, 1932) is a member of the phillipsite group. The mineral occurs in a variety of intrusive rocks, in gneiss and some metalliferous veins. It occurs with chabazite at Bodenmais, Bavaria; with agate geodes at Oberstern, Rhineland; in metalliferous veins at Andreasberg, Harz Mountains, Germany. In Scotland it occurs at Argyll, Dumbarton and Stirling. In the United States it occurs in gneiss on New York Island, Western Lake Superior. Harmotome also occurs in the Craigmont Mine near Merritt, British Columbia.

Strontium

CELESTITE $(SrSO_4)$ (Vlasov, 1966, pp. 178-182) is a member of the barite group of minerals and the most common isomorphous impurities are barium and calcium. The isomorphous series between celestite and barite has been synthesized but the mid range between 40 and 70 per cent barite is very rarely reported in nature. Isostructural mixtures of celestite and anhydrite have been synthesized but the intermediate compositions are rarely reported in nature. SiO_2, Al_2O_3, Fe_2O_3 and possibly MgO occur as mechanical impurities in celsetite.

Celestite is the most important strontium mineral and it occurs most commonly in hydrothermal deposits associated with lead-zinc, barite and fluorite minerals. Such occurrences have been reported in dolerite in Tunisia; barite-witherite veins of Kopet-Dagh, Turkmen, U.S.S.R.; low temperature fluorite deposits, Kentucky, U.S.A.; fluorite-rare earth and fluorite-uranium deposits, Birch Island (82-50), British Columbia (Preto, 1978); lead-zinc veins in the Frontenac Lead Mine (31-09) and the fluorite veins at Madoc, Ontario; and in carbonatite host rocks. Rarely celestite occurs alone in hydrothermal veins or with zeolites in amygdules.

Celestite most frequently occurs in sedimentary rocks that include evaporite beds. The mineral is either distributed as originally deposited or was redistributed by diagenetic processes. Celestite in this association has been reported in the Permian sulphate-dolomite rocks of the Volga, Cisurals and Timan; Cambrian rocks of Angara; Cretaceous rocks of central Asia, U.S.S.R. and Carboniferous gypsiferous beds of Dorchester (Dorbeck) (21-31), New Brunswick and Kaiser Celestite (11-27) and Rear Black River (11-21), Nova Scotia. Strontium is concentrated by brine evaporation, metabolism of living organisms and diagenetic alteration of sedimentary rocks. Fossils from normal marine basin sediments may be enriched in strontium and celestite has been reported in radiolaria tests, ammonite and brachiopod shells. Celestite concentrations form as the result of diagenesis and strontium redistribution by circulating ground water, for example nodules and veins in the lower Palaeozoic limestone of southern Ontario, Frazer-Duntile quarry (31-02) and Cape Robert (41-02).

STRONTIANITE $(SrCO_3)$(Vlasov, 1966, p. 174) was formerly a commercial source of the element strontium. Varieties of the mineral include calcio-strontianite and barium strontianite in which calcium and barium substitute for strontium. The former replaces up to Ca:Sr-1:4.5 and calcite and strontianite form an isomorphous series. Rarely strontianite contains some lead. No comprehensive structural study has been done, however, the mineral is a member of the aragonite class of carbonates.

Strontianite, one of the most common strontium minerals, generally occurs in low temperature hydrothermal veins with celestite, barite, calcite, sulphides and other minerals. The best known examples occur in Strontian, Argyll, Scotland; the United States; fluorite veins at Kuli-Kolon, Tadzhik, barite veins at Kopet-Dagh, Turkmen and kimberlite pipes in Yakutia in the U.S.S.R. Epigenetic veins and geode fillings in limestones and marls occur in West Germany and California. Replacement deposits in limestone have been reported at Kara-Oba, Kazakhstan. Under supergene conditions strontianite inverts to celestite.

The former mineral is reported in relatively few sites in Canada, none of which is of commercial importance. Crusts occur on pebbles and strontianite veinlets occur in the underlying bedrock in the Horsefly placer mine (93-01), British Columbia. The mineral occurs in a carbonatite-alkaline rock complex at Oka, Quebec (31-97). It also occurs in veins in sedimentary rocks on Corney Brook (11-59) Cape Breton Island, Nova Scotia.

SVANBERGITE $(SrAl_3(SO_4)(PO_4).(OH)_6$(Vlasov, 1966, p. 188), a sulphopho-sphate of aluminum and strontium, is a member of the beudantite mineral group. These minerals are characterized by isomorphous replacement of Sr^{2+} by Pb^{2+} rather than Sr^{2+} by Ca^{2+}. Weak replacement by Al^{3+} and Fe^{3+} also was noted. The heating curve shows an endothermal effect commencing at 80° and peaking at 430-590° and an exothermal peak at 900°C marking the decomposition of the mineral. The mineral fuses to a glass at 1,080°C.

Svanbergite occurs in quartzite in association with kyanite, pyrophyllite, hematite and rutile near Horrsjoberg, Wermland and Nasum, Kristianstad, Sweden. It is also associated with pyrophyllite in an andalusite mine near Hawthorn, Nevada. Svanbergite occurs in diamond-bearing gravels of Rio San Jose near Paraguassu, Bahia, Brazil (Dana, 1949). It fills cracks and caverns in stony bauxites in the Urals, U.S.S.R.

GOYAZITE $(SrAl_3(PO_4)(OH)_5.H_2O)$ (Vlasov, 1966, p. 193) a hydrated strontium aluminum phosphate is also known by the synonyms hamlinite and bowmanite. Apparently there is an isomorphous series goyazite-gorceixite in which barium substitutes for strontium, calcium replaces strontium and fluorine replaces OH groups to a limited extent.

Goyazite is found in diamond-bearing sands, crusting solution cavities in dolomite, in pegmatite dykes, in residual weathered crusts, with authigenic barite-quartz-pyrite cementing breccia overlying salt domes and in organogenic limestone. These occurrences are distributed from Brazil to the U.S.A. and the U.S.S.R. The processes include development of alluvial placers, epigenetic and hydrothermal deposition and authigenic deposition of the mineral.

LAMPROPHYLLITE ($Na_4Sr_2Fe_2Ti_4Si_6O_{25}F_2$) (Vlasov, 1966, p. 207) one of the few strontium-bearing silicates has one synonym: molengraffite and one variety barium lamprophyllite. Lamprophyllite is characteristic of nepheline syenites and the associated pegmatites that are leucocratic and carry anomalous amounts of strontium and fluorine. The mineral has been reported from such occurrences in the U.S.S.R., Norway and South Africa. It is generally concentrated in the fine-grained marginal zones or in the aegirine-rich central zones of differentiated pegmatites. It is also associated with microcline, nepheline, ramsayite, murmanite, lomonosovite, eudialyte and aegirine.

Fluorine (Table XII)

FLUORITE (CaF_2) (Dana, 1951) is the most widespread ore mineral of fluorine. It occurs in rocks of all, except ultramafic, compositions. The main compositional variation in fluorite is the substitution of Y^{3+} for Ca^{2+} and a partial series exists between CaF_2 and YF_3 although the latter compound is unknown in nature. Yttrofluorite and yttrocerite are naturally occurring veinlet variants of fluorite although neither is abundant nor widespread.

Fluorite has been reported in a wide range of deposit types. It occurs as a constituent of veins, as intergranular cement in clastic and pyroclastic sediments, in hotspring deposits, and as joint-fillings and miarolitic cavities in granites. Fluorite occurs alone or with varying amounts of lead and silver sulphides, quartz, calcite, dolomite, barite and celestite in veins. It also occupies solution and collapse structures in limestone or dolomite where it is associated with celestite, anhydrite, gypsum, dolomite and sulphur. Sandstones and sometimes water-lain lacustrine pyroclastic rocks are cemented by intergranular fluorite and the pyroclastic rocks locally carry large amounts of low grade fluorite such as north of Rome, Oregon and near Rome, Italy. Hotspring deposits like those at Wagon Wheel Gap, Colorado are locally enriched in fluorine. Fractures and miarolitic cavities in fluorine-rich felsic and alkaline intrusive rocks are filled by fluorite during the late hydrothermal stage of differentiation. Contact metasomatic deposits, greisen and skarn zones are commonly enriched in fluorite. Epithermal veins are hosted by felsic pyroclastic rocks at Lake Ainslie East, Nova Scotia; by Ordovician limestone and Grenville rocks in southeastern Ontario; iron formation at Thunder Bay, Ontario and brecciated Devonian shale north of Liard Crossing, British Columbia. Solution and collapse cavity fillings are reported from Mile 397, Alaska Highway west of Fort Nelson. Granitic rocks host fluorite-mineralized joints and miarolitic cavities at Whiteman Creek (82-29) and Eaglet (93-02) properties, British Columbia; Hasbala Lake (64-01), Manitoba; and St. Lawrence, Newfoundland. Pneumatolytic deposits of fluorite have been reported at Lower Canoe Lake (21-04), Nova Scotia and Cassiar and Seagull Batholiths, British Columbia and Yukon.

CRYOLITE (Na_3AlF_6) (Dana, 1951) is an important alumino-fluoride once mined in Greenland but now synthesized from fluorite and used as the electrolyte for reducing alumina to aluminum. The mineral is the most common of the alumino-fluorides and these have been classified into four structural groups; isolated octahedrons, chain structures, sheet and network structures. These minerals consist mainly of sodium, aluminum and fluorine with lesser amounts of calcium, strontium, magnesium and either OH – or H_2O groups. Cryolite sometimes contains traces of Ca, Mn or organic material. Aluminum can substitute for Na and O for F in the artificial compounds. Cryolite alters readily to other aluminum fluorides.

Cryolite was formerly produced at Ivigtut, Greenland but the source has now been largely exhausted. Here, the mineral occurs in a pegmatite body hosted by a granite stock that intrudes gneisses. Cryolite has also been reported at Miask, Ilmen Mountains, U.S.S.R.; Sallent, Huesca Province, Spain and El Paso County, Colorado. The mineral has also been identified in the alkaline rocks of the St. Hilaire stock (31-106).

FLUORAPATITE ($Ca_5(PO_4)_3F$) (Dana, 1951) is probably the most common variety of apatite and the main commercial source of phosphorus, and potentially the world's largest source of fluorine. Fluorapatite crystals sometimes have oriented rutile needles or monazite crystals as inclusions. Zoned or overgrown crystals of different members of the apatite series have been reported. The common accessory apatite of igneous rocks often shows deeply coloured or pleochroic cores due to inclusions.

The series fluorapatite, chlorapatite and hydroxylapatite represent a series in which F, Cl and OH substitute to nearly pure end members. Co_2 is sometimes reported as an essential constituent. C also substitutes for P in a few cases. Mn can substitute for Ca up to at least Mn:Ca = 1:5.7; Sr for Ca up to Sr:Ca = 1:6.8 and rarely Mg substitutes for Ca. Alkalis are rarely reported in trace amounts in ordinary apatite, but are present in larger amounts in isostructural and probably isomorphous silicate phosphates. Fluorapatite, fluorian hydroxylapatite and carbonatian apatite are the most important members of the group whereas pure chlorapatite, carbonate-apatite and hydroxylapatite are rare and limited in distribution. Fluorian varieties occur as accessory minerals in most igneous rocks in the form of early-formed microscopic crystals. They also occur in large late-magmatic segregations in alkalic igneous rocks(Kola Peninsula, U.S.S.R.), in pegmatites of both felsic and mafic rocks, in magmatic deposits, and high temperature hydrothermal veins. Apatite is common in regionally metamorphosed rocks such as marble, talc and chlorite schist and in contact metamorphic aureoles. It also occurs in marine phosphate beds and in the derived residual products, as well as in the leaching products of guano.

The mineral is widely distributed. In Canada single crystals up to 225 kg have been found in Grenville marble, in veins and contact deposits in southeastern Ontario. Apatite occurs in low-grade bedded phosphate deposits in the Canadian Cordillera south of Crowsnest Pass. Massive deposits have been reported in carbonatite complexes in Ontario and South Africa.

TOPAZ ($(AlF)_2SiO_4$) (Dana, 1932) is an aluminum fluor-silicate of widespread occurrence and a potential source of fluorine. The mineral usually contains hydroxyl groups that replace part of the fluorine. The main use of the mineral at present is as a gemstone.

Topaz characteristically occurs in felsic intrusive rocks and rhyolites, in veins and cavities and as a product of pneumatolytic activity in country rock schists and gneisses. It is often associated with fluorite, tourmaline and cassiterite. Topaz is reported in some pegmatites. The mineral alters to compact masses of muscovite.

Gem material has been collected from a number of sites in U.S.S.R., Europe, Africa and North America. Non-gem material is probably more widespread than reported because of the difficulty of identifying the mineral under field conditions. Topaz occurs at several localities in Canada none of which has produced gem quality material. These localities include Seagull Creek (105-3), Yukon Territory, where topaz is associated with fluorite, columbite and tourmaline in pegmatite; a site near Jasper House, Alberta, where pebbles occur in a river gravel; a site near Tete Jaune Cache, British Columbia where topaz is associated with large mica plates; Shatford Lake (52-98) and Winnipeg River areas, Manitoba, where topaz occurs in pegmatites; Sturgeon Lake, Ontario, where topaz is in hornblende syenites; the Grenville Province, Quebec, where topaz is associated with mica in pegmatites; New Brunswick, where topaz occurs with wolframite, molybdenite and cassiterite; and, east of Maconet Bay, Newfoundland (Traill, 1970, 1973), where topaz is in an amazonite aplite dyke.

Other fluorine-bearing minerals include a variety of silicate minerals with high fluorine contents that occur in pegmatites, pneumatolytic and metasomatic deposits. MICAS are the greatest accumulator of fluorine, both the primary micas of igneous rocks and the secondary micas produced by weathering processes. The mineral species include biotite, phlogopite, muscovite, lithium micas and secondary clay minerals. AMPHIBOLES are second to micas as accumulators of fluorine and the greatest concentrations are found in the more alkaline varieties and the lowest concentrations in those in extrusive igneous rocks and metamorphic rocks.

Accessory silicates including tourmaline, sphene, allanite, vesuvianite and humite contain from trace to minor fluorine. TOURMALINE includes three sub-varieties schorlite, dravite and elbaite. They occur in pegmatites and hydrothermal and pneumatolytic deposits. SPHENE is most abundant in alkalic intrusive rocks and it indicates the presence of an excess of fluorine in the crystallizing melt or mineralizing fluids. Sphene in felsic or alkalic pegmatites contains less fluorine than sphene hosted by the parent intrusive rocks. ALLANITE accumulates fluorine as it crystallizes from felsic magmas. VESUVIANITE(idocrase) and LAMPROPHYLLITE are fluorine-bearing silicates characteristically found in skarn deposits and alkalic pegmatites. Members of the HUMITE GROUP: clinohumite, norbergite and chondrite accumulate fluorine mainly in metasomatic deposits. Norbergite accumulates more fluorine (up to 13.5%) than the other members of the humite group.

APPENDIX C

Appendix C is an index to the barium, strontium and fluorine deposits in Canada on which information has been compiled in the course of this project. The index consists of tables based on geographical location (Table 32) and alphabetical sequencing of the property names (Table 33). The geographical locations are tabulated in order from west to east across Canada and within N.T.S. squares from the southwest corner. Table 32 has nine columns from left to right that present N.T.S. number, sequence number, as many as four of the elements recorded for a property, property development code, syngenetic classification, epigenetic classification, latitude, longitude and property name. The term "occurrence" in the property development code column refers to one or other of "prospect", "showing" or "subshowing" as defined in the record definition (see p. 182). The term "past producer" does not necessarily mean that either Ba, Sr or F were produced, only that some commodity (e.g. Pb, Zn, etc.) was produced from the report. Element lists that do not contain Ba, Sr, or F mean one or more of these elements is present but is not one of the four most abundant elements. Table 33 has six columns from left to right: property name, (N.T.S.) number, sequence number, political province, tectonic province and tectonic subprovince.

The information in the tables contains some abbreviations and shortened words to fit the space allocated for such data in the computer records. Standard abbreviations have been used for the names of political provinces, chemical elements and points of the compass. Additional abbreviations include the following.

N.T.S.	National Topographic System
SEQ	Sequence number
Rx	Rocks
Ign	Igneous
Intrus	Intrusive rocks
Extrus	Extrusive rocks

Table 32. Geographical index of Canadian barium-strontium- and fluorine-bearing occurrences

N T S NO	SEQNO NO	ELEMENTS 1	2	3	4	DEVELOPMENT CODE 1979	SYNGENETIC CLASSIFICATION	EPIGENETIC CLASSIFICATION	LATITUDE	LONGITUDE	NAME
116	001	F	SN			OCCURRENCE	SEDIMENTARY RX		64 01 18	139 03 00	HUNKER GERMAINE CR PLACERS
115	001	BA				OCCURRENCE		VEINS	61 25 00	139 20 00	KLUANE L
	002	F				"	IGN INTRUS RX		61 26 20	138 10 00	ROCKSLIDE CR 1
	003	"	MO	CU		"	"		61 29 20	138 10 00	ROCKSLIDE CR 2
	004	AU	PB	BA	ZN	"	SEDIMENTARY RX		62 05 00	137 15 00	UPR NANSEN CR
	005	BA	AU	SB		"		VEINS	62 16 00	137 03 00	EMMONS HILL PPTY
	006	AG	PB	BA		PAST PRODUCER		"	62 43 00	138 49 00	CASINO CREEK
	007	AU	BA	W	SN	OCCURRENCE	SEDIMENTARY RX		63 59 00	136 52 30	ARIZONA CR
	008	"	BA	SN		PAST PRODUCER	"		63 55 12	139 19 03	GRAND FORKS
	009	PB	BA	AG	AU				63 55 25	140 35 00	BUTLER GULCH-BEN CON
106	001	BA				OCCURRENCE	SEDIMENTARY RX		64 01 00	129 22 30	RAIN-SNOW CLAIMS
	002	"	PB	S		DEVELOPED PROSPECT	"		64 65 00	131 20 00	KEN CLAIMS
	003	ZN	PB	BA		"			65 57 00	130 43 00	RT
105	001	F				OCCURRENCE	IGN INTRUS RX		60 01 00	135 30 30	WHEATON R S-FORK
	002	"	B	SN		"	"		60 04 00	131 16 30	PARTRIDGE CR
	003	B	F	NB	TR	"	"		60 07 00	131 15 00	SEAGULL CREEK
	004	F	B			"	"		60 07 00	131 30 00	DORSEY SHOWING
	005	"	W	PB	CU	DEVELOPED PROSPECT		VEINS	60 08 12	130 26 00	FIDDLER YUKON MINE
	006	BA	SB	PB	AG	OCCURRENCE		"	60 11 00	135 18 00	FLEMING-PORTER CLS
	007	SB	PB	AG	ZN	"		"	60 15 00	134 43 00	CARIBOU-CHIEFTAIN HILLS
	008	F				"		"	60 34 35	131 31 15	E OF WOLF LAKE
	009	"	B			"		"	60 39 00	131 10 20	WOLFE L AREA
	010	ZN	PB	AG	BA	"		UNCLASSIFIED	61 27 30	132 39 00	ZINC GROUP(MM)
	011	BA	PB			"		VEINS	61 50 00	133 02 30	NORMA LUCKY LU CLS
	012	W	CU			PRODUCER		REPLACEMENT DEP	61 59 00	128 14 00	CANADA TUNGSTEN MINE
	013	ZN	PB	AG	BA	DEVELOPED PROSPECT	IGN EXTRUS RX		62 12 30	133 02 00	SWIM LAKE PPTY
	014	"	PB	BA		"	"		62 15 00	133 12 00	VANGORDA CR PPTY
	015	BA	ZN	PB	AG	PRODUCER	"		62 21 30	133 22 00	FARO- NO1 AND 2
	016	"				DEVELOPED PROSPECT	SEDIMENTARY RX		62 42 00	129 47 00	ORO SHOWING
	017	ZN	BA	CU		OCCURRENCE	METAMORPHIC RX		62 50 45	130 01 00	GUNN CLAIMS
	018	BA				"	SEDIMENTARY RX		62 57 00	131 10 00	S MACMILLAN R
	019	"				"	"		63 01 24	130 36 30	TEA CLAIMS
	020	"				"		VEINS	63 01 45	130 06 10	CLYDE SMITH CLS
	021	"				DEVELOPED PROSPECT		"	63 04 00	130 12 40	MOOSE GRP MACMILLAN PASS
	022	ZN	PB	BA		"	SEDIMENTARY RX		63 07 30	130 17 30	JASON CLAIMS
	023	BA				OCCURRENCE	"		63 08 00	131 25 30	N MACMILLAN R
	024	AG	ZN	PB	BA	"		REPLACEMENT DEP	63 08 30	130 13 30	TOM GRP (HBE A N D D)
	025	BA				PAST PRODUCER	SEDIMENTARY RX		63 17 12	130 36 30	LORRAIN(BAROID)
	026	"				OCCURRENCE	"		63 17 40	130 32 00	BAR PROSPECT
	027	"				"	"		63 18 70	131 13 30	SCOT CLAIMS
	028	"				"	"		63 38 30	129 40 00	WISE CLAIMS
	029	"				"	"		63 43 00	128 52 45	BA CLAIMS
	030	"				"	"		63 50 40	129 07 30	ART EKWI S
	031	AG	PB	ZN		"		VEINS	63 54 24	135 15 36	BELLEKENO MINE
	032	PB	AG	[illegible]		DEVELOPED PROSPECT		"	63 57 04	135 10 51	SILVER BASIN CLAIM
105	033	BA				OCCURRENCE	SEDIMENTARY RX		63 58 00	129 18 30	ART EKWI N
	034	"				"	"		63 04 00	130 15 00	GARY
	035	"	PB	AG	ZN	"			63 13 00	130 34 00	KOBUK
	036	"	CU	PB	ZN	"	SEDIMENTARY RX		63 17 00	130 38 00	HESS
	037	PB	ZN	AG	BA	DEVELOPED PROSPECT	"		62 15 00	133 10 00	GRUM
	038	BA				OCCURRENCE	"		62 22 00	133 30 00	URN
	039	PB	ZN	BA	F	"	IGN EXTRUS RX		61 36 00	132 26 00	CZERPNOUGH
	040	"	BA	FE		"	"		61 35 00	132 30 00	SNOB
	041	BA	PB	ZN		"	SEDIMENTARY RX		62 37 00	129 45 00	TANG
	042	"	PB	ZN	FE	"	"		63 00 00	130 04 00	PETE
	043	"				"	"		61 55 00	133 00 00	GK
104	001	BA				OCCURRENCE		VEINS	56 05 00	129 50 00	INDEPENDENCE GOLD
	002	CU	AU	BA		"		"	56 06 30	129 45 30	GEORGE COPPER GROUP
	003	PB	AG	BA	ZN	"		"	56 07 30	129 44 30	RED TOP GROUP
	004	"	ZN	AG	AU	PAST PRODUCER		"	56 07 45	130 00 30	SILVER TIP
	005	BA				OCCURRENCE		"	56 08 00	129 45 30	BARITE GOLD MINES LTD
	006	"	PB	CU		"		"	56 08 15	129 55 00	LUCKY JIM
	007	AG	ZN	PB	BA	PAST PRODUCER		"	56 08 21	129 52 36	TERMINUS MINES
	008	PB	CU	BA	AG	OCCURRENCE		"	56 08 30	129 55 00	RUBY CLAIM(SHUNIAH MINE)
	009	AG	BA			"		"	56 10 00	129 53 00	MOUNTAIN BOY GROUP
	010	BA	AG	PB	ZN	"		"	56 29 00	130 27 30	CUMBERLAND GR. MOUNT MADGE
	011	PB	ZN	CU	AG	"		"	57 43 12	130 19 48	SF PROPERTY
	012	CU	AU	AG	BA	"		"	58 11 24	129 52 48	DALVENIE(BIG CHIEF)
	013	ZN	AG	CU	BA	"		"	58 40 10	132 38 30	MANVILLE GRP (BIG BULL)
	014	"	CU	PB	AU	PAST PRODUCER		REPLACEMENT DEP	58 44 00	133 35 00	TULSEQUAH CHIEF-BIG BULL
	015	BA	PB	ZN		OCCURRENCE		VEINS	59 02 00	128 05 00	VALE CLAIM GRP
	016	BE	F	SN		"	IGN INTRUS RX		59 08 00	129 46 00	LOW GRADE CLAIMS
	017	BA	PB	AG	ZN	DEVELOPED PROSPECT		VEINS	59 11 45	129 12 00	ATAN-AUGUST CL GRPS
	018	"	PB	CU	AG	OCCURRENCE		REPLACEMENT DEP	59 12 30	129 13 30	CARLICK GRP - ATAN LAKE
	019	W	BE	SN	F	"		VEINS	59 39 00	130 28 00	BLUE LIGHT
	020	SN	F			"	IGN INTRUS RX		59 40 12	133 25 12	SILVER DIAMOND
	021	BE	F	BI	W	"	"		59 59 30	131 36 00	LOGJAM CREEK

N T S NO	SEQNO NO	ELEMENTS 1	2	3	4	DEVELOPMENT CODE 1979	SYNGENETIC CLASSIFICATION	EPIGENETIC CLASSIFICATION	LATITUDE	LONGITUDE	NAME
103	001	BA	W	AU		OCCURRENCE		VEINS	54 29 06	128 25 30	ANNIE LAURIE CL
	002	AU	AG	CU	BA	"		"	54 30 00	128 28 00	LUCKY SEVEN GRP
	003	PB	ZN	AG	BA	"		"	55 05 45	129 52 00	ENGINEER CLAIM
	004	BA				"		"	55 08 00	130 00 03	WARATAH CLAIM
	005	AU	AG	PB	BA	"		"	55 25 00	129 25 00	LAST CHANCE GRP.
	006	AG	PB	AU	BA	PAST PRODUCER		"	55 29 00	129 28 00	WOLF CLAIM(LOC 184)
	007	PB	ZN	BA		OCCURRENCE		UNCLASSIFIED	55 29 00	129 29 00	CASEY CAMP
	008	BA	ZN			"		VEINS	55 30 00	129 25 00	HIGHLAND GRP.
	009	CU	ZN	PB	BA	"		"	55 32 45	129 26 30	FOX GRP
	010	ZN	PB	BA		"		"	55 33 00	129 21 00	FOX GROUP(OAK R)
	011	PB	ZN	BA		"		"	55 34 00	129 16 30	HOMEBUSH CLMS
	012	BA	AG	PB	ZN	"		"	55 40 30	129 30 30	DAVID COPPERFIELD GRP.
	013	AG	PB	ZN	BA	PAST PRODUCER		"	55 41 00	129 30 30	DOLLY VARDEN MINE-WOLF GRP
	014	"	BA			OCCURRENCE		"	55 41 15	129 31 00	NORTHSTAR CLAIM
	015	"	PB	BA		"		"	55 41 30	129 30 30	RUBY GRP TORIC MINE
103	016	PB	AG	BA	CU	OCCURRENCE		REPLACEMENT DEP	55 41 45	129 30 15	MUSKATEER GROUP
	017	ZN	PB	BA	AG	"		VEINS	55 43 00	129 31 00	CLIMAX GRP
	018	"	PB	AG	BA	PAST PRODUCER		"	55 57 30	130 49 00	BLACK HILL EXCELSIOR GRP
	019	AG	PB	BA		OCCURRENCE		"	55 59 00	129 53 00	EVENING SUN CLAIM
095	001	PB	ZN	BA		OCCURRENCE		REPLACEMENT DEP	60 21 10	127 24 55	QUARTZ LAKE
	002	BA	ZN	PB		DEVELOPED PROSPECT		UNCLASSIFIED	60 21 30	127 24 30	MEL-JEAN CLAIMS
	003	"				OCCURRENCE	SEDIMENTARY RX		60 47 30	126 41 00	LAST MTN
	004	"				"	"		60 48 00	126 41 00	LAST MOUNTAIN (2.8 MI.NW)
	005	"				"	"		60 48 50	126 41 30	LAST MOUNTAIN (4.4MI.NW)
	006	CU	BA	PB		"		VEINS	61 11 30	122 46 35	LIN CLS LIARD R
094	001	ZN	PY	PB	BA	OCCURRENCE		VEINS	56 06 36	124 52 00	GORDON CLS
	002	PB	ZN	PY	BA	"		"	56 07 20	125 02 00	WEBER GROUP
	003	ZN	BA	PB		"		"	56 08 24	124 55 00	DAVIES CLAIMS
	004	AG	PB	ZN	BA	"		REPLACEMENT DEP	56 09 00	125 04 00	BEVERLY GROUP
	005	PB	ZN	AG	BA	"		"	56 27 00	125 35 00	BURN(1-20)
	006	"	ZN	AG	AG	"		"	56 30 00	125 35 24	RAIN(1-10)
	007	CU	PB	ZN	BA	"		VEINS	57 15 36	123 52 48	TRI
	008	ZN	PB	BA	F	"		"	57 22 00	123 52 00	EGG FOO
	009	"	PB	BA		"		REPLACEMENT DEP	58 28 00	124 20 24	CTV CBC HOPE DODO
	010	BA	F			"		VEINS	58 41 00	124 48 00	ALASKA HWY MI 397
	011	"	F			"		"	58 55 00	125 43 00	MUNCHO L
	012	"				"		"	58 57 20	125 31 40	NONDA CR
	013	"				"		"	59 02 15	125 36 00	SULPHUR CREEK
	014	F				"		"	59 04 36	125 39 00	SHOW
	015	BA	F			"	SEDIMENTARY RX		59 09 30	125 52 00	ALASKA HWY MI 472
	016	"	F			DEVELOPED PROSPECT		VEINS	59 27 00	126 05 00	GEM(LIARD CROSSING)
	017	F	BA			"		"	59 27 00	126 05 30	CAMP CLIFF NICK BAR
	018	"	BA			"		"	59 30 00	126 06 00	CORAL(LIARD CROSSING)
	019	"	BA			"		"	59 30 45	126 05 00	FIRE(LIARD CROSSING)
	020	"	BA			"		"	59 32 00	126 04 45	TAM(LIARD CROSSING)
	021	"	BA			"		"	59 35 45	126 08 15	TEE(LIARD CROSSING)
	022	BA	PB	ZN		OCCURRENCE		"	59 44 12	127 14 00	WOLF(BEAR)
	023	"				"	SEDIMENTARY RX		59 48 00	125 27 00	SCATTER RIVER
	024	"	ZN	PB	AG	DEVELOPED PROSPECT	IGN INTRUS RX		58 05 00	125 50 30	DRIFTPILE CREEK
	025								57 40 30	125 20 45	MOUNT ALCOCK
	026					PRODUCER			57 30 45	125 09 00	CIRQUE
	027	BA	PB	ZN	CU	DEVELOPED PROSPECT	IGN INTRUS RX		57 18 30	124 24 30	ELF
	028					"	SEDIMENTARY RX		57 28 00	124 50 30	FLUKE
	029					OCCURRENCE			57 24 30	125 00 00	PIE
093	001	AU	BA	SR		OCCURRENCE	SEDIMENTARY RX		52 20 00	121 20 30	HORSEFLY PLACER
	002	F				"		VEINS	52 30 45	120 49 30	EAGLET FLUORITE
	003	BA	ZN	AG	BA	"		"	52 34 45	126 27 00	NIFTY 1-5 AND THUNDER CLS
	004	PB	ZN	BA	AG	"		"	53 55 30	121 28 00	BONANZA (PRINCE GEORGE)
	005	ZN	PB	AG	BA	PAST PRODUCER		UNCLASSIFIED	54 05 00	126 43 00	MIDNIGHT (CHISHOLM) CLAIM
	006	PB	CU	BA	F	OCCURRENCE		VEINS	54 06 00	125 45 00	MONA PROPERTY
093	007	AG	PB	ZN	BA	OCCURRENCE		REPLACEMENT DEP	54 18 30	126 38 30	BUCK GROUP
	008	"	BA	PB	ZN	"		VEINS	54 27 00	125 24 00	SILVER ISLAND PROPERTY
	009	CU	PB	BA		"		"	54 28 45	126 15 30	AILPORT PROSPECT(JOKER)
	010	"	PB	ZN	BA	"		"	54 29 24	126 25 48	APEX(ROAD SHOWING)
	011	BA	CU	PB		"		"	54 34 05	126 13 40	EVERGREEN CLAIMS
	012	HG	SB	AS	BA	PAST PRODUCER		"	54 37 30	124 26 30	PINCHI LAKE MINE MERCURY C
	013	BA	ZN			OCCURRENCE		"	55 08 00	127 37 00	MACDONALD GR-KATHERINE CLM
	014	"				"	SEDIMENTARY RX		55 32 00	124 06 00	OMINECA QUEEN
	015	ZN	PB	BA	AG	"		REPLACEMENT DEP	55 56 00	124 45 00	VERNON, DONNA
092	001	CU	ZN	AG	BA	PAST PRODUCER		REPLACEMENT DEP	48 56 30	123 46 30	TWIN J MINE
	002	"	AU	BA		OCCURRENCE		VEINS	49 30 00	121 45 00	SENECA(ZENITH) DEP
	003	ZN	PB	CU	AG	"	IGN EXTRUS RX		49 34 00	125 35 00	PRICE PPTY(WESTERN ML)
	004	CU	ZN	PB	AG	PAST PRODUCER		REPLACEMENT DEP	49 34 30	125 35 30	LYNX MINE(WESTERN ML)
	005	ZN	BA	CU	PB	"		"	49 36 00	123 09 00	BRITANNIA MINE FAIRVIEW
	006	"	BA	CU	PB	"		"	49 36 24	123 09 00	BRITANNIA MINE JANE
	007	CU	ZN	PB	AG	"		"	49 36 42	123 08 24	BRITANNIA MINE BLUFF
	008	FE	ZN	PB	F	OCCURRENCE		VEINS	49 47 00	120 20 00	CLAREMONT GROUP
	009	BA				"		"	49 48 45	120 12 30	EL PASO GRP
	010	PB	ZN	BA		PAST PRODUCER		UNCLASSIFIED	50 03 09	120 45 30	LEADVILLE GRP.(LUCKY TODD)
	011	AU	BA			"		VEINS	50 45 30	122 47 00	PIONEER MINE

N T S	SEQNO	ELEMENTS				DEVELOPMENT	SYNGENETIC	EPIGENETIC	LATITUDE	LONGITUDE	NAME
NO	NO	1	2	3	4	CODE 1979	CLASSIFICATION	CLASSIFICATION			
086	001	AU	F	CU	PB	OCCURRENCE		VEINS	64 35 00	115 33 00	DINGO GROUP
	002	AG	CU	F		"		"	66 01 00	118 07 00	BONANZA GRP-DOWDELL POINT
	003	U	AG	BA	F	"		"	66 05 24	118 02 30	COBALT GRP ELDORADO MINE
	004	"	BA	CU		"		"	66 22 00	117 50 00	ACHOOK IS
	005	CU	BA			"		"	67 22 00	115 07 00	SPECTROAIRS HA CLAIMS
	006	BA	CU			"		"	67 35 00	115 15 00	MACKENZIE MINING (KIL)
	007	CU	BA			"		"	67 36 00	117 00 00	TRI GROUP (1 TO 4)
085	001	PB	ZN	F		OCCURRENCE		VEINS	61 15 00	112 30 00	SNUFF CHANNEL (E.OF)
	002	F	PB	ZN	AG	"		"	61 16 30	112 33 00	BULL MOOSE CLAIM
	003	CU	F			"		"	61 29 30	112 32 30	THUBUN RIVER
	004	BA	CU	AG		"		"	62 07 30	112 39 00	R ROCK 89 TALTHEILEI NAR
	005	AU	AG	F	MO	"		"	62 30 00	114 20 00	ARSENO GRP
	006	F				"		REPLACEMENT DEP	63 33 00	115 55 00	BIG SPRUCE LAKE
082	001	PB	ZN	AG	BA	OCCURRENCE		VEINS	49 02 00	117 18 40	SHENANGO-RAINBOW CLS
	002	BA				"		"	49 02 24	114 44 45	DESOLATION CREEK S
	003	"	CU			PAST PRODUCER		"	49 02 30	114 00 00	PHILLIPS CR
	004	CU	BA			OCCURRENCE		UNCLASSIFIED	49 05 00	114 58 20	ALICE WILDA BETTY GREEN
	005	PB	WO	ZN		"		REPLACEMENT DEP	49 06 30	117 13 18	EMERALD MINE
	006	BA				"		VEINS	49 06 36	114 51 00	FENSTER CR S
	007	"				"		"	49 09 00	114 53 15	FENSTER CR N
	008	CU	PB	ZN	F	"		"	49 13 30	114 41 30	ROK CAT
	009	F	BA	U		PAST PRODUCER		"	49 15 36	118 27 15	ROCK CANDY FLUORITE MINE
	010	MO	CU	F		OCCURRENCE		"	49 16 48	118 03 00	WEWA(RAM)
082	011	BA	AG	PB	ZN	OCCURRENCE		VEINS	49 25 00	119 05 00	GOLD DROP CLAIM
	012	AG	PB	ZN	F	PAST PRODUCER		"	49 40 42	116 50 30	KOOTENAY FLORENCE
	013	PB	ZN	AG	CU	OCCURRENCE		"	49 44 40	116 54 30	EARLY BIRD CLAIM
	014	AG	PB	ZN	F	PAST PRODUCER		REPLACEMENT DEP	49 45 00	116 57 00	NO. ONE
	016	MO	U	F		DEVELOPED PROSPECT	IGN INTRUS RX		49 45 15	116 57 20	SILVER HOARD CLAIM
	017	PB	ZN	FE	CU	PAST PRODUCER		VEINS	49 45 20	116 55 30	HIGHLANDER(HIGHLAND MINE)
	018	BA	AG	PB		OCCURRENCE		"	49 45 30	117 23 06	CALUMET-HECLA GRP
	019	AG	CU	BA		"		"	49 47 18	115 23 36	ANNA GRP
	020	"	PB	ZN	AU	PAST PRODUCER		"	49 47 30	117 24 00	OTTAWA MINE
	021	"	PB	BA		"		"	49 48 00	117 21 18	SPECULATOR GRP
	022	"	PB	ZN	BA	"		"	49 48 30	117 22 00	LITTLE TIM
	023	"	PB	ZN	BA	"		"	49 48 45	117 24 48	ALMA(MYRTLE) GRP
	024	"	PB	ZN	F	"		"	49 49 00	117 20 00	PEGLEG(NEEPAWA GRP)
	025	BA	PB			OCCURRENCE		"	49 50 00	117 30 00	JUNE, SILVER TIP, ALL BLUE
	026	AG	PB	ZN	BA	PAST PRODUCER		"	49 51 00	117 17 00	HIGHLAND LIGHT
	027	PB	ZN	AG	F	"		"	49 55 45	117 21 24	GALENA FARM MINE CURRIE GR
	028	AG	PB	ZN	F	OCCURRENCE		"	49 59 33	117 20 00	MOUNTAIN CHIEF GROUP
	029	F				"					
	030	BA				"	IGN INTRUS RX		50 13 00	119 28 42	WHITEMAN CR GREEN GABLES
	031	PB	AG	BA		DEVELOPED PROSPECT		VEINS	50 15 00	115 50 00	WINDERMERE (4 MI.SE.OF)
	032	BA	PB	CU	AG	OCCURRENCE		"	50 19 00	116 14 00	YORNOC DAVE (40CLS)
	033	"	AG	PB	ZN	"		"	50 19 00	116 15 00	SHELLY CAROLE
	034	CU	PB	ZN	AG	PAST PRODUCER		REPLACEMENT DEP	50 20 00	116 23 00	SILVER SPRAY GRP
	035	"	AG	BA	PB	OCCURRENCE		"	50 20 00	116 26 15	MINERAL KING
	036	BA	PB	ZN		"		VEINS	50 20 30	116 30 00	COPPER KING IMPERIAL
	037	"	FE			PAST PRODUCER		REPLACEMENT DEP	50 25 54	115 52 54	LUCKY(CAMERON)
	038	F	BA			OCCURRENCE		VEINS	50 27 15	116 06 00	LARRABEE PPTY
	039	BA	PB	CU		"		"	50 32 00	117 14 00	FIVE MILE POINT
	040	U	NB	F		"		"	50 42 00	117 06 00	RENO CLS
	041	PB	ZN	FE	F	"	SEDIMENTARY RX		50 45 00	116 42 30	BUGABOO VOWELL FORSTER CRS
	042	BA				PRODUCER		REPLACEMENT DEP	50 48 00	117 58 45	WIGWAM GROUP
	043	PB	ZN	AG	BA	PAST PRODUCER		VEINS	50 49 48	116 19 30	BRISCO SALMON WAMINECA CLS
	044	BA	ZN			PRODUCER		REPLACEMENT DEP	50 56 06	116 28 18	SILVER GIANT MINE
	045	AG	PB	ZN	BA	PAST PRODUCER		VEINS	51 01 30	116 39 00	PARSON(HILLTOP SNOWDROP)
	046	"	PB	ZN	CU	OCCURRENCE		"	51 06 36	119 49 42	HOMESTAKE GRP
	047	F				"		"	51 07 48	119 45 36	TWIN MOUNTAIN(MAX HOPE)
	048	PB	ZN	BA	CU	"		UNCLASSIFIED	51 08 00	117 56 00	
	049	AG	PB	F		"	SEDIMENTARY RX		51 08 00	118 24 00	RIVER JORDAN DEPOSIT
	050	ZN	PB	CU	F	"		VEINS	51 17 20	116 38 30	PORCUPINE CREEK
	051	F	SR	U	CE	DEVELOPED PROSPECT		"	51 19 40	116 32 30	SUNDAY CLAIM
	052	ZN	PB	BA	F	"		UNCLASSIFIED	51 34 30	119 54 30	REXSPAR(BIRCH ISLAND)
								REPLACEMENT DEP	51 45 20	118 54 00	IT IN TO(RUDDOCK CR)
075	001	BA	CU			OCCURRENCE		VEINS	62 08 00	111 38 00	PEKANATUI POINT
	002	"				"		"	62 22 48	110 50 54	SNOWDRIFT-MARY CLS
	003	"	CU			"		"	62 25 15	110 22 12	LUX CLAIM GRP
	004	U	CU	F		"		"	62 27 00	110 19 00	REX GROUP (ABCDE STEVENS)
	005	CU	BA			"		UNCLASSIFIED	62 30 00	110 30 00	TOCHATWI BAY
	006	BA				DEVELOPED PROSPECT		VEINS	62 40 00	110 45 00	PEGGY(FORMERLY MARY)
072	001	BA				OCCURRENCE	SEDIMENTARY RX		49 30 00	109 30 00	CYPRESS LAKE
068	001	ZN	PB	BA		OCCURRENCE		VEINS	75 23 42	096 55 18	POLARIS MINE
064	001	F				OCCURRENCE	IGN INTRUS RX		59 45 00	101 55 00	MASBALA LAKE
	002	"				"	"		59 55 00	099 15 00	MUNROE L GRANITE
	003	"				"	"		60 00 00	100 00 00	NUETLIN L N ENNANDAI L S
063	001	SR	AU	CU		OCCURRENCE		VEINS	54 42 00	101 03 00	ISL. IN THIRD CRANBERRY L.
	002	CU	NI	F	MO	"		REPLACEMENT DEP	55 28 06	097 34 30	PARTRIDGE CROP LAKE AREA

N T S	SEQNO		ELEMENTS			DEVELOPMENT	SYNGENETIC	EPIGENETIC	LATITUDE	LONGITUDE	NAME
NO	NO	1	2	3	4	CODE 1979	CLASSIFICATION	CLASSIFICATION			
062	001	BA				OCCURRENCE		VEINS	51 23 00	096 33 00	PIPESTONE ISLAND
052	001	BA				OCCURRENCE		VEINS	48 03 30	089 29 30	BIG TROUT BAY
	002	AG	BA			"		"	48 04 22	089 22 22	VICTORIA ISLAND
	003	"	PB	ZN	BA	PAST PRODUCER		"	48 05 48	089 18 18	JARVIS ISLAND
	004	"	BA	ZN	PB	"		"	48 06 12	089 17 06	SPAR ISLAND-PRINCE PPTY
	005	F	AG	AU	ZN	OCCURRENCE		"	48 07 45	089 18 45	PRINCE"S MINE
	006	CU	BA			"		"	48 08 54	089 16 45	MINK ISLAND
	007	AG	BA			"		"	48 10 29	089 09 04	THOMPSON ISLAND
	008	F				"		"	48 10 45	090 11 00	MNG LOC 277
	009	BA	PB	ZN	AG	PAST PRODUCER		"	48 11 05	089 07 36	SOUTH MCKELLAR ISLAND
	010	"				OCCURRENCE		"	48 12 40	089 40 20	HIDDEN TREASURE MINE
	011	AG	F	FE	PB	DEVELOPED PROSPECT		"	48 14 04	089 54 00	AUGUSTA MINE
	012	F	BA			OCCURRENCE		"	48 14 15	089 55 00	SCRIPTURE"S VEIN
	013	AG	PB	ZN	F	PAST PRODUCER		"	48 15 00	089 52 30	SILVER MTN MINES
	014	F	BA	PB	CU	OCCURRENCE		"	48 15 15	089 49 00	R 110 SILVER FALLS
	015	"	AG			DEVELOPED PROSPECT		"	48 15 15	089 52 00	CROWN POINT MINE
	016	"	BA	ZN	PB	OCCURRENCE		"	48 15 23	089 51 00	LYBSTER TP (R64)
	017	AG	BA	F		"		"	48 15 23	089 50 30	R 70 LYBSTER TP
	018	F	PB	ZN		"		"	48 16 00	089 50 17	R 111 LYBSTER TP
	019	"	PB	ZN		"		"	48 15 45	089 50 00	R 115 TCHIATIN"S VEIN
	020	"				"		"	48 16 30	089 57 30	STAR MINE
	021	BA	PB	ZN		"		"	48 17 00	089 43 45	HYMER"S VEIN
	022	F	PB	ZN		"		"	48 17 00	089 51 12	R 135 WOODSIDE"S VEIN
	023	"				"		"	48 17 36	090 05 30	LOCATION 124 NE WHITEFISHR
	024	"	PB			"		"	48 17 55	089 41 10	PEERLESS MINE (R158)
	025	AG	PB	ZN	BA	PAST PRODUCER		"	48 18 22	089 39 43	CRESWEL(PORCUPINE MINE)
	026	"	PB	ZN	F	OCCURRENCE		"	48 18 23	089 39 42	CRESWEL(BADGER MINE)
	027	"	ZN	PB	F	PAST PRODUCER		"	48 18 28	089 36 15	RABBIT MTN MINE
	028	"	F	ZN	PB	OCCURRENCE		"	48 18 34	089 36 18	RABBIT MTN JR MINE ML 57
	029	"	PB	F		PAST PRODUCER		"	48 18 40	089 39 30	CRESWEL(SILVER CR MINE)
	030	"	ZN	PB	F	"		"	48 18 56	089 39 30	CLIMAX KEYSTONE MINE
	031	"	ZN	PB	PY	"		"	48 19 05	089 38 30	BEAVER MINE(ML T97)
	032	"	F	ZN		OCCURRENCE		"	48 19 05	089 39 24	WEST BEAVER MINE
	033	"	CO	ZN	PB	PAST PRODUCER		"	48 19 27	088 48 18	SILVER ISLET MINE
052	034	AG	ZN	BA		OCCURRENCE		VEINS	48 19 35	089 38 20	BEAVER JR
	035	ZN	PB	F	FE	DEVELOPED PROSPECT		"	48 19 45	089 34 20	BIG BEAR VEIN
	036	AG	CU	ZN	F	"		"	48 19 45	089 37 50	ELGIN VEIN
	037	BA	F		PB	OCCURRENCE		"	48 19 45	089 44 15	T 143 PITCH CR
	038	"	F	AG		"		"	48 20 08	089 29 00	PARSONS MINE LILY OF VALLY
	039	CU	FE	PB	F	"		"	48 20 40	089 24 35	KAMINISTIKWIA R
	040	F	AG	BA		"		"	48 20 50	089 31 35	FEDERAL MINE COPELAND VEIN
	041	"	ZN	PB		DEVELOPED PROSPECT		"	48 20 50	089 35 25	PAIPOONGE TP
	042	AG	PB	ZN	F	OCCURRENCE		"	48 21 00	089 35 23	VICTORIA MINE
	043	PB	ZN	F		"		"	48 21 20	089 29 45	PARASSEUX RAPIDS VEIN
	044	AS	AG	BA	PB	PAST PRODUCER		"	48 21 30	088 38 24	EDWARD ISLAND
	045	F	PB			OCCURRENCE		"	48 21 45	089 35 30	JONES PPTY
	046	BA	CU			"		"	48 22 30	088 37 15	PORPHYRY ISLAND
	047	"	PB	ZN		"		"	48 23 40	089 21 15	JOHN PPTY
	048	"	CL	PB	CU	DEVELOPED PROSPECT		"	48 23 45	089 23 10	NEEPATYRE MINE-WALBRIDGE
	049	F	ZN	CU		OCCURRENCE		"	48 23 45	089 23 30	ALGOMA MINE
	050	AG	BA	F	ZN	DEVELOPED PROSPECT		"	48 24 00	089 32 45	KELLOW PPTY(ML42)
	051	F	AG	ZN		OCCURRENCE		"	48 24 30	089 15 30	HEWITSON QUARRY
	052	BA	AG	F	ZN	"		"	48 24 33	089 15 48	MCINTYRE LOT 53
	053	"	AG	F	ZN	"		"	48 25 30	089 14 40	STEWART QUARRY MAY ST
	054	"	AG	ZN	CU	"		"	48 27 40	089 13 40	PORT-ARTHUR SILVER 1
	055	F	PB	CU		"		"	48 27 50	089 15 15	LOT 17 OSMUN VEIN
	056	"				"		"	48 28 10	089 28 27	TRENKS PPTY
	057	AG	ZN	PB	F	PAST PRODUCER		"	48 28 39	089 12 13	SHUNIAH MINE-DUNCAN MINE
	058	PB	AG	ZN	F	"		"	48 29 10	089 09 14	THUNDERBAY MINE (58)
	059	F	CU			OCCURRENCE		"	48 29 12	089 10 21	MACGREGOR TP
	060	AG	PB	ZN	CO	PAST PRODUCER		"	48 30 49	088 58 21	BECK MINE
	061	ZN	PB	FE	F	OCCURRENCE		"	48 31 15	088 57 25	LOT 1A MACGREGOR TP
	062	BA	PB	CU		"		"	48 31 18	088 54 30	BUCK ISLAND
	063	AG	PB	ZN	BA	PAST PRODUCER		"	48 31 20	088 59 05	THREE A MINE
	064	F				OCCURRENCE		"	48 32 05	088 53 08	LAMBERT ISLAND
	065	BA	F			"		"	48 32 12	088 53 45	PALETTE IS
	066	F	BA	PB	ZN	"		"	48 33 36	088 49 09	KNOBEL PT
	067	PB	BA	ZN	AG	"		"	48 35 30	088 46 30	BLENDE LAKE VEIN
	068	"	AG	F	BA	"		"	48 36 00	088 42 30	SILVER L VEINS
	069	F				"		"	48 36 50	090 20 12	LOCH ERNE
	070	"	PB	ZN	AG	"		"	48 39 00	088 43 45	ANDERSON VEIN
	071	BA	ZN	PB		"		"	48 39 00	088 46 45	LOON LAKE
	072	"				"		"	48 40 15	088 41 48	JOHNSTON SHOWING
	073	"	PB			"		"	48 40 21	088 39 45	PIKE LAKE VEINS
	074	PB	CU	AG	AU	PAST PRODUCER		"	48 40 50	088 37 17	ENTERPRISE MINE
	075	"	ZN	BA	CU	OCCURRENCE		"	48 41 00	088 40 30	DETROIT-ALGOMA MINE
	076	BA	PB	ZN	CU	"		"	48 42 00	088 31 45	KARIES CLAIM
	077	PB	ZN	AG	BA	"		"	48 43 20	088 51 25	SANTACK
	078	"	BA	ZN		"		"	48 46 15	088 38 00	KEMERER PPTY
	079	BA	PB	ZN		"		"	48 46 15	088 39 00	MILLAR PPTY
	080	PB	ZN	AG	F	PAST PRODUCER		"	48 46 30	088 44 45	OGEMA MINE
	081	BA	PB	ZN		OCCURRENCE		"	48 46 45	088 41 15	GOODMORNING LAKE
	082	PB	BA			"		"	48 48 26	088 37 52	ST CLAIR PPTY
	083	BA	PB	ZN		"		"	48 49 15	088 37 50	ANDERSON-BINGHAM PPTY
	084	PB	ZN	BA		PAST PRODUCER		"	48 49 50	088 40 30	DORION MINE

N T S NO	SEQNO NO	ELEMENTS				DEVELOPMENT CODE 1979	SYNGENETIC CLASSIFICATION	EPIGENETIC CLASSIFICATION	LATITUDE	LONGITUDE	NAME
		1	2	3	4						
052	085	BA	PB	ZN		PAST PRODUCER		VEINS	48 50 20	088 39 20	BISHOP CLS 5-6L
	086	PB	ZN	BA		OCCURRENCE		"	48 51 04	088 45 00	LEBEL PPTY
	087	"	ZN	BA		"		"	48 51 05	088 38 42	THUNDER BAY PB-ZN PPTY
	088	BA	PB	ZN	CU	"		"	48 59 00	088 19 00	NIPIGON TP
	089	"	AG	CU		"		"	49 00 00	088 05 00	TB6038 CLAIM
	090	PB	ZN	BA	CU	"		"	49 00 15	088 04 30	MAZOKAMA BAY PROS.TB4588SE
	091	"	ZN	BA	F	"		"	49 01 00	088 05 00	GORDON CL 6038
	092	ZN	PB	BA		"		"	49 01 30	088 01 00	OZONE SIDING LEWIS SEYLER
	093	"	PB	BA	F	"		"	49 01 15	088 02 30	OZONE SIDING MCL TB4588
	094	LI	F	BE		"	IGN INTRUS RX		49 40 00	095 32 00	GLEN (LUCY NO.1 CLAIMS)
	095	F				"		VEINS	49 53 35	090 51 25	SEATON ISLAND
	096	SR				"	IGN INTRUS RX		49 57 30	090 48 00	WAHL PROSPECT
	097	LI	F	NB		PAST PRODUCER	"		50 21 06	095 21 36	OLD SILVER LEAF PGMT
	098	SN	F	BE	NB	OCCURRENCE	"		50 23 00	095 27 00	SHATFORD L(E-END)
	099	F	SN	NB	U	"	"		50 23 12	095 28 30	TIN ISLAND
	100	BE	SN	F	AS	"	"		50 26 24	095 22 42	RUSH AND STANNITE GROUPS
	101	LI	BE	F		"	"		50 37 45	095 27 42	EAGLE CLAIMS
042	001	BA	CU	PB	ZN	OCCURRENCE		VEINS	48 00 18	080 35 24	BIEDERMAN CLAIM
	002	CU	PB	F		"		"	48 01 05	080 32 05	BROOKBANK PPTY
	003	BA	F			PAST PRODUCER		"	48 05 15	082 09 10	CRYDERMAN (RAVENA) PROP
	004	"	AU	SR		"		"	48 09 20	080 03 30	LAKE SHORE GOLD MINE
	005	AU	BA			"		"	48 09 30	080 03 15	WRIGHT HARGREAVES MINE
	006	BA	F	AG	ZN	"		"	48 16 55	080 59 40	PREMIER LANGMUIR MINE
	007	"				OCCURRENCE		"	48 21 30	080 31 00	WELCOME L
	008	AU	F			"		"	48 32 30	081 38 30	LOUISAKOFF-HILL CLS
	009	F				"		"	48 43 45	086 38 00	MAINLAND OPPOSITE PIC IS
	010	BA	F	AG		"		"	48 46 45	087 07 15	BLACK R FALLS
	011	F				"		"	48 47 00	087 08 00	TERRACE BAY
	012	"	BA			"		"	48 53 15	087 37 00	TP 87
	013	P	F			DEVELOPED PROSPECT	IGN INTRUS RX		49 20 00	082 51 00	CARGILL
041	001	SR				OCCURRENCE	SEDIMENTARY RX		45 50 00	081 44 30	MANITOUWANING
	002	"				"	"		45 59 45	082 48 30	CAPE ROBERT
	003	CU	BA			PAST PRODUCER		VEINS	46 18 00	083 47 00	BRUCE COPPER MINES
	004	"	BA			OCCURRENCE		"	46 29 00	083 24 00	CHENEY MINE
	005	PB	ZN	AG	CU	PAST PRODUCER		"	46 38 30	084 08 30	JARDUN MINE
	006	BA	CU	AU		OCCURRENCE		"	46 39 26	080 31 03	MOUNT AETNA MINE
	007	"				DEVELOPED PROSPECT		"	47 28 00	081 00 00	EXTENDER MINERALS
	008	"				OCCURRENCE		"	47 34 00	085 00 15	DEVILS WAREHOUSE IS
	009	"				DEVELOPED PROSPECT	IGN INTRUS RX		47 37 00	080 40 00	LAWSON TP
	010	"	AU			OCCURRENCE		VEINS	47 39 00	081 17 00	WEST SHININGTREE AREA
	011	"				PAST PRODUCER		"	47 39 18	080 33 33	EBY OR SCOTT CL
	012	NB	BA			OCCURRENCE	IGN INTRUS RX		47 43 00	083 18 00	FIRESAND R CARBONATITE
	013	AG	FE	CO	NI	DEVELOPED PROSPECT		VEINS	47 43 25	080 26 55	NORTH AMERICAN SILVER
	014	BA				OCCURRENCE		"	47 44 15	080 26 30	JOHN CAMERON
	015	"				PRODUCER		"	47 53 45	080 46 00	YARROW BARITE MINE
	016	F				OCCURRENCE		"	47 58 30	080 35 45	HARVEY CL NO. 18285
040	001	SR				OCCURRENCE	SEDIMENTARY RX		42 36 00	082 06 00	AMHERSTBURG
	002	"				"		REPLACEMENT DEP	43 16 00	081 08 00	ST MARY'S
032	001	F	MO			OCCURRENCE		VEINS	48 05 00	077 40 00	BOURLAMAQUE TP
	002	AU	F			PAST PRODUCER	IGN INTRUS RX		48 05 00	078 05 00	CANADIAN MALARTIC GML
	003	F				OCCURRENCE		VEINS	48 05 00	079 10 00	COOK COPPER AND FLUORITE
	004	"	CU	PB	ZN	"		"	48 08 00	079 07 00	BEAUCHASTEL L
	005	PB	ZN	AG	BA	"		"	48 11 38	079 57 05	MALLARD LAKE PROJ
	006	AU	F	PB	FE	"		"	48 15 00	079 25 00	BLOCK 8 CLS
	007	MO	F	BI	BE	PAST PRODUCER		"	48 17 15	077 59 45	LACORNE MINE
	008	"	F			OCCURRENCE		"	48 18 30	077 57 30	LACORNE TP
	009	"	BE	F		PAST PRODUCER		"	48 20 00	078 20 00	BLOCK F
	010	"	BE	LI	F	OCCURRENCE	IGN INTRUS RX		48 20 30	077 59 00	GOYETTE-SUP PROPERTY
	011	PB	F			"	"		48 45 00	079 25 00	OKIKODASIK R MOUTH
	012	F				DEVELOPED PROSPECT		VEINS	49 15 00	077 00 00	FLORENCE R G M
	013	"	FE			OCCURRENCE		"	49 16 00	079 04 42	LEMAIRE TP
	014	"	FE			"		"	49 30 00	076 05 00	QUEBEC STURGEON RIVER M L
	015	NI	CU	ZN	MO				48 20 18	078 11 24	ATAMAN
031	001	CA	BA			PRODUCER		VEINS	44 15 45	076 29 45	FRONTENAC QUARRY
	002	BA	F			PAST PRODUCER		"	44 17 15	076 33 00	WOODRUFFE MINE
	003	F	BA			"		"	44 26 20	077 24 30	PALMATEER
	004	"				"		"	44 26 35	077 25 06	JONES
	005	"	BA			OCCURRENCE		"	44 26 50	077 32 05	WILLIAMS PPTY
	006	BA				"			44 27 15	076 19 45	DOG LAKE
	007	F				PAST PRODUCER		VEINS	44 27 30	077 32 00	HERRINGTON SOUTH
	008	"				OCCURRENCE		"	44 27 50	077 25 50	WRIGHT
	009	SR	PB			PAST PRODUCER		"	44 28 00	076 30 30	FRONTENAC LEAD MINE
	010	F	BA			"		"	44 28 00	077 26 15	HOWARD(HILL)
	011	"	BA			"		"	44 28 05	077 26 50	JOHNSON MINE
	012	"	BA			"		"	44 28 20	077 26 52	NOYES MINE
	013	"	BA	ZN	SR	"		"	44 28 25	077 28 25	BLAKELEY MINE
	014	"				"		"	44 28 40	077 29 55	SOUTH REYNOLDS
	015	"				"		"	44 28 45	077 30 45	MCILROY MINE
	016	"	BA	SR	FE	"		"	44 28 50	077 28 05	PERRY LAKE

N T S NO	SEQNO NO	ELEMENTS 1	2	3	4	DEVELOPMENT CODE 1979	SYNGENETIC CLASSIFICATION	EPIGENETIC CLASSIFICATION	LATITUDE	LONGITUDE	NAME
031	017	"	BA	SR	FE	"		"	44 28 55	077 28 15	PERRY MINE
	018	BA	F			DEVELOPED PROSPECT		"	44 28 55	077 28 45	COE PPTY
	019	F	CA	BA		"		"	44 28 55	077 32 40	WALLBRIDGE PPTY
	020	"	BA			PAST PRODUCER		"	44 29 06	077 32 30	LEE SENIOR
	021	"	BA			"		"	44 29 15	077 28 50	ROGERS
	022	"				OCCURRENCE		"	44 29 15	077 32 15	MADOC TP 5
	023	"				"		"	44 29 15	077 33 20	HERRINGTON
	024	"				PAST PRODUCER		"	44 29 20	077 29 15	KILPATRICK (DETOMAC)
	025	"				"		"	44 29 20	077 29 40	NORTH REYNOLDS
	026	"	BA			OCCURRENCE		"	44 29 30	077 32 45	STEWART MINE
	027	"				PAST PRODUCER		"	44 29 35	077 29 45	KEENE PPTY
	028	BA				OCCURRENCE		"	44 29 40	076 40 00	BOTTING OCCURRENCE
	029	F	BA			PAST PRODUCER		"	44 29 40	077 29 50	BAILEY MINE
	030	F				OCCURRENCE		VEINS	44 29 45	077 32 00	MADOC TP 4
	031	"				PAST PRODUCER		"	44 29 45	077 33 20	MILLER
	032	"				"		"	44 29 45	077 33 30	PONTON
	033	FE	CU	F		OCCURRENCE		"	44 29 45	077 37 15	MARMORA
	034	F	BA			PAST PRODUCER		"	44 29 50	077 31 00	LEE JUNIOR
	035	"				OCCURRENCE		"	44 29 55	077 28 30	HUNTINGDON
	036	SR	BA			"		"	44 30 00	076 35 30	NORDEN VERONA DEP
	037	F	BA			PAST PRODUCER		"	44 30 00	077 29 00	HILL PPTY
	038	"	BA			OCCURRENCE		"	44 30 10	077 33 25	WILLIAM REYNOLDS
	039	SI	BA			PAST PRODUCER		"	44 30 20	076 04 00	LYNDHURST QUARTZ MINE
	040	SR	BA	BA		OCCURRENCE		"	44 30 30	076 07 10	BUELL(LANSDOWNE)
	041	F	BA			"		"	44 30 30	077 31 00	MCBEATH
	042	"				"		"	44 30 30	077 33 45	ROOKS
	043	"	BA			"		"	44 31 30	077 34 30	PLAIN
	044	BA				"		"	44 32 15	076 38 20	HOWES PROSPECT
	045	"	F			DEVELOPED PROSPECT		"	44 34 00	077 25 00	MADOC TP 2
	046	F				OCCURRENCE		"	44 34 45	077 32 00	MADOC TP 3
	047	BA	F			DEVELOPED PROSPECT		"	44 35 00	077 30 30	MADOC TP 1
	048	"	PB			OCCURRENCE		"	44 36 30	076 34 35	JOHN MURPHY
	049	PB	BA			"		"	44 36 30	077 39 10	METHUEN LEAD VEIN
	050	"	BA			"		"	44 36 45	076 34 15	JAMES MURPHY
	051	"	BA			DEVELOPED PROSPECT		"	44 37 33	076 33 30	MURPHY-HICKEY PPTY
	052	"	BA	ZN		OCCURRENCE		"	44 37 35	076 33 30	MURPHY-HICKEY
	053	BA	PB			"		"	44 38 30	076 32 10	BUTTERILL
	054	"	PB	ZN		DEVELOPED PROSPECT		"	44 38 30	076 33 15	ROBINSON GROUP
	055	PB	BA			OCCURRENCE		"	44 38 45	076 32 00	BURRIDGE RD
	056	BA				"		"	44 39 40	076 39 40	MCEWEN PROSPECT
	057	"	PB			DEVELOPED PROSPECT		"	44 40 20	077 32 30	HOLLANDIA LEAD MINE
	058	AG	CO	ZN	PB	OCCURRENCE		"	44 41 00	077 39 30	KATHERINE LEAD MINES
	059	PB	BA			"		"	44 42 00	077 38 30	MURPHY MINE
	060	BA	PB	ZN		"		"	44 42 00	078 37 00	CROWN KING LEAD PROSPECT
	061	PB	ZN	BA		PAST PRODUCER		"	44 42 09	078 36 35	UNION CR LEAD MINE
	062	BA	PB			OCCURRENCE		"	44 45 50	077 40 40	LOMBARD PPTY
	063	"				PAST PRODUCER		"	44 48 39	076 21 30	FARRELL PPTY
	064	"	F			OCCURRENCE		"	44 48 45	076 36 54	JOHN CRAWFORD I
	065	"				PAST PRODUCER		"	44 50 10	076 15 10	N BURGESS
	066	"	CU	F		OCCURRENCE		"	44 50 15	076 43 25	JOHN CRAWFORD II
	067	F	BA			"		REPLACEMENT DEP	44 51 18	077 07 50	BARRIE
	068	AG	PB	BA		"		VEINS	44 52 05	077 34 30	CHRYSLER LEAD PPTY
	069	BA				"		"	44 53 00	076 24 00	BATHURST STA
	070	"	PB	AG		"		"	44 53 00	077 33 00	CASHEL TP
	071	"	PB	ZN		"		"	44 53 45	077 31 45	GUNTER
	072	P	F			"		"	44 59 00	078 07 50	CANADA RADIUM
	073	F	U	TH		DEVELOPED PROSPECT		"	45 01 06	078 11 45	CARDIFF U MINE B-C ZONES
	074	U	SR			PAST PRODUCER	IGN INTRUS RX		45 01 15	077 55 30	FARADAY U MINE
	075	"	F	TH		DEVELOPED PROSPECT		VEINS	45 01 54	078 12 49	CARDIFF U MINE A E ZONES
	076	F				OCCURRENCE		"	45 02 30	078 15 00	MONMOUTH TP
	077	NB	TH	U	F	PAST PRODUCER	IGN INTRUS RX		45 02 50	078 31 20	BASIN DEPOSIT
	078	F				OCCURRENCE		VEINS	45 03 20	078 11 25	RICHARDSON
	079	"				PAST PRODUCER		"	45 03 25	078 10 25	TRIPP FARM
	080	"				DEVELOPED PROSPECT		"	45 03 34	078 10 22	MONTGOMERY PPTY
031	081	BA	F			OCCURRENCE		VEINS	45 03 48	078 10 00	SCHICKLER FARM
	082	F				"		"	45 03 50	075 10 45	DWYER PPTY
	083	"	P			"		"	45 04 00	078 07 30	CARDIFF TP
	084	"	U			DEVELOPED PROSPECT	IGN INTRUS RX		45 04 35	078 09 30	CLARK PPTY
	085	BA	CU	SB	SB	"		REPLACEMENT DEP	45 07 00	076 44 00	CLYDE FORKS
	086	"	ZN	AG	HG	PAST PRODUCER		VEINS	45 10 00	076 10 00	RAMSEY MINE
	087	FD	F			"	IGN INTRUS RX		45 10 00	077 49 15	MACDONALD QUARRY
	088	FLD	F	U		"	"		45 10 45	077 49 00	WOODCOX FELDSPAR MINE
	089	SR	BA			"		VEINS	45 15 34	076 39 45	WILDER(CALABOGIE)
	090	BE	F	NB		"	IGN INTRUS RX		45 19 30	077 24 45	CANADIAN BERYLLIUM
	091	"	FLD	U	NB	"	"		45 20 00	077 23 00	CASEY HILL
	092	SR				OCCURRENCE		VEINS	45 21 00	075 43 15	NEPEAN TP
	093	"	BA			"	SEDIMENTARY RX		45 22 20	075 44 45	FRAZER DUNTILE QUARRY
	095	PB	ZN	BA	F	PAST PRODUCER		VEINS	45 26 30	076 15 24	KINGDON OR GALETTA PB MINE
	096	"	CA	ZN		OCCURRENCE		"	45 27 30	076 16 00	CAMPBELL SHOWING
	097	BA				PAST PRODUCER		"	45 28 00	075 50 00	PINK MINE
	098	NB	TA	BA	SR	"	IGN INTRUS RX		45 30 00	074 01 54	ST LAWRENCE COLUMBIUM MINE
	099	F				OCCURRENCE		VEINS	45 30 30	073 36 00	MOUNT ROYAL
	100	SR				"	SEDIMENTARY RX		45 30 55	073 32 10	ST HELEN ISLAND
	101	BA	F			"		VEINS	45 31 20	076 13 10	ONSLOW TP 2
	102	"	F			PAST PRODUCER		"	45 31 20	076 14 15	QUYON
	103	"	F			OCCURRENCE		"	45 31 25	076 11 35	ONSLOW TP 1
	104	"				"		"	45 31 35	076 13 30	ONSLOW R3 L13
	105	"	F			"		"	45 31 53	076 12 47	ONSLOW R4 L13
	106	"				PAST PRODUCER		"	45 32 00	075 46 00	FOLEY MINE
	107	F				OCCURRENCE		"	45 33 00	073 10 00	MOUNT ST HILAIRE
	108	BA	F			PAST PRODUCER		"	45 33 00	075 47 00	IRONSIDE MINE

N T S NO	SEQNO NO	ELEMENTS 1	2	3	4	DEVELOPMENT CODE 1979	SYNGENETIC CLASSIFICATION	EPIGENETIC CLASSIFICATION	LATITUDE	LONGITUDE	NAME
031	109	"				OCCURRENCE		"	45 33 15	075 44 45	HULL TP
	110	FE	BA			PAST PRODUCER		"	45 33 20	075 32 15	HAYCOCK MINE
	111	BA	ZN			OCCURRENCE		"	45 33 45	075 36 30	BERREA
	112	SR				"		"	45 34 00	074 32 00	HAWKSBURY
	113	MO	U	F		PAST PRODUCER	IGN INTRUS RX		45 34 33	076 14 48	MOSS KINE
	114	BA	PB	ZN		DEVELOPED PROSPECT		VEINS	45 34 45	075 29 15	GORMAN PPTY-ANGERS STA
	115	P	MI	F		PAST PRODUCER		"	45 35 30	075 38 30	RAINVILLE(DUGAS) MINE
	116	MIC	P	F		"		"	45 35 30	075 38 45	WALLINGFORD MINE
	117	BA	PB	ZN		OCCURRENCE		"	45 35 45	075 29 00	BOURRET SHOWING
	118	F				DEVELOPED PROSPECT		"	45 36 15	076 50 30	JOHNSTON
	119	ZR	SR			OCCURRENCE	IGN INTRUS RX		45 37 10	073 32 00	ST MICHEL SILL
	120	F				"		VEINS	45 37 12	076 46 40	COLE MINE
	121	BA	P			PAST PRODUCER		"	45 38 15	075 36 45	BLACKBURN MINE
	122	"	TI			OCCURRENCE		"	45 40 00	075 38 15	LITTLE DAM LAKE
	123	F				"		"	45 40 12	076 48 45	COBDEN
	124	"	P			"		"	45 41 00	076 46 12	ROSS 1
	125	"				"		"	45 41 45	076 44 45	ROSS 2
	126	"	LI	MIC		PAST PRODUCER	IGN INTRUS RX		45 42 30	075 46 40	OLD LEDUC MINE
	127	"	U	TH		OCCURRENCE		VEINS	45 46 30	076 44 50	CALUMET CONTACT U MINES
	128	"	U	TH		DEVELOPED PROSPECT		"	45 46 40	076 43 00	CALUMET URANIUM ML
	129	"	P			PAST PRODUCER		"	45 47 30	075 32 45	NORTH STAR MINE
	130	MIC	F			"	IGN INTRUS RX		45 50 00	075 30 20	DERRY TP
	131	F	U	TH	RE	OCCURRENCE	"		45 50 30	075 35 50	VILLENEUVE MICA MINE
	132	"	U	TH	CU	"		REPLACEMENT DEP	45 54 54	076 38 42	PONTEFRACT A-2 3
	133	F	U	TH	RE	PAST PRODUCER		VEINS	45 58 00	076 32 30	MATTE ZONE
	134	NB	U	BA		DEVELOPED PROSPECT	IGN INTRUS RX		46 15 00	079 30 00	NEWMAN DEPOSIT
	135	FE	NB	U	BA	OCCURRENCE		VEINS	46 16 00	079 52 45	IRON ISLAND
	136	F				"	IGN INTRUS RX		46 17 00	078 28 30	CAMERON TP
	137	C	F			"		VEINS	46 32 00	075 14 00	BOYER
	138	F				"	IGN INTRUS RX		46 32 30	075 29 00	CAMPBELL TP
	139	"				"	"		46 33 00	075 50 00	AUMOND TP
	140	"				PAST PRODUCER	"		46 33 30	075 13 45	BRODIE QUARRY
	141	P	F			OCCURRENCE	"		46 38 00	075 55 00	SICOTTE TP
	142	F				"		VEINS	46 46 25	072 15 25	ST UBALD PARISH
	143	"	U	TH		DEVELOPED PROSPECT		UNCLASSIFIED	45 00 15	078 12 06	WILBERMERE LAKE
	144	BA				OCCURRENCE		VEINS	00 45 00	007 55 00	KINBURN
	145	NB	F						43 33 48	074 17 12	ATAMAN
030	001	SR				OCCURRENCE	SEDIMENTARY RX		43 48 00	080 00 00	CREDIT FORKS
024	001	BA	U	TH		OCCURRENCE		VEINS	56 40 28	068 51 18	EDGAR LAKE AREA
022	001	F	PB			OCCURRENCE		VEINS	48 15 00	069 00 00	ANSE-A-LA CAVE
	002	BA	PB	ZN		"		"	48 21 00	068 34 37	ST FABIEN TP
	003	"	PB			"		"	48 22 00	068 45 00	NICHOLAS-RIOUX SEIGNURY
	004	NB	MO	U	BA	PRODUCER	IGN INTRUS RX		48 33 00	071 12 00	ST HONORE
	005	PB	ZN	BA	CU	OCCURRENCE		VEINS	48 46 20	066 04 00	LYALL AND BEIDELMAN PROP.
	006	"	ZN	F	BA	"		"	48 49 15	066 10 00	BRANDY BROOK
021	001	BA	PB			OCCURRENCE		VEINS	44 45 00	066 45 00	GRAND MANAN IS
	002	"	FE	PB	CU	"		"	44 45 00	066 50 00	WOOD ISLAND
	003	"	FE	PB	CU	"		"	44 46 00	066 45 00	SAWPIT COVE
	004	F				"		"	44 48 24	064 19 36	LOWER CANOE LAKE
	005	PB	ZN	BA		"		"	44 57 06	066 53 06	CAMPOBELLO ISLAND
	006	"	ZN	BA	F	"		"	45 03 00	066 50 48	FRYE ISLAND
	007	BA				DEVELOPED PROSPECT		"	45 05 16	064 08 13	LOWER BURLINGTON(CABIN BR)
	008	MN	BA			PAST PRODUCER		"	45 09 18	064 11 08	MACUMBER-DEEP HOLLOW MINES
	009	CA	F	SR		OCCURRENCE		"	45 09 28	064 10 41	CHEVERIE CLIFFS
	010	FE	MN	BA		DEVELOPED PROSPECT		"	45 09 49	064 04 40	GOSHEN MINE
	011	MN	BA			"		"	45 11 45	064 02 36	STURGIS-FEUCHTWANGER MINES
	012	BA	MN	CA		OCCURRENCE		"	45 12 00	064 02 45	FEUCHTWANGER PPTY
	013	"	PB	ZN	CU	PAST PRODUCER		REPLACEMENT DEP	45 12 20	064 02 30	WALTON (MAGNET COVE)
	014	"	MN	CA		OCCURRENCE		VEINS	45 13 37	064 00 21	SHAW-CHURCHILL MINE
	015	F				"	SEDIMENTARY RX		45 18 00	066 06 00	STETSON-CUTLER QUARRY
	016	PY	ZN	PB	CU	PAST PRODUCER		VEINS	45 24 35	071 49 45	MOULTON HILL-ALDERMAC MINE
	017	BA				OCCURRENCE		"	45 25 47	064 53 53	SPICERS COVE
	018	ZN	F	SN	FE	DEVELOPED PROSPECT		"	45 26 30	066 48 45	MT PLEASANT MINE
	019	BA				PAST PRODUCER		"	45 26 35	064 02 38	EUREKA(DUNCAN MINE)
	020	"	F			OCCURRENCE		"	45 26 58	064 00 19	EAST R OF FIVE ISLANDS
	021	PB	ZN	F		"		"	45 31 20	066 21 13	QUEENS BROOK FLUORITE
	022	MN	BA	F		PAST PRODUCER		"	45 36 45	065 26 50	MARKHAMVILLE MINE
	023	BA				OCCURRENCE		VEINS	45 38 02	064 02 29	BLACK (BROCK) RIVER
	024	U	F			"		"	45 40 00	067 06 00	YORK MILLS
	025	"	F			"		"	45 41 00	067 02 30	MANNERS SUTTON
	026	F				"		"	45 44 00	067 00 00	HARVEY STA
	027	"				"		"	45 42 00	067 12 00	LISTER"S MILLS
	028	BA				"		REPLACEMENT DEP	45 43 00	064 39 00	ST MARY"S POINT
	029	ZN	PB	CU	BA	DEVELOPED PROSPECT		VEINS	45 46 22	071 18 45	CUPRA MINE
	031	BA	SR			"		"	45 56 30	064 31 45	DORCHESTER(DORBECK)
	032	CU	F			OCCURRENCE		UNCLASSIFIED	45 57 00	064 24 00	BEECH HILL
	033	BA	F	CU	PB	DEVELOPED PROSPECT		VEINS	46 01 00	064 32 00	MEMRAMCOOK COPPER MINE
	034	"				OCCURRENCE		"	46 08 35	064 47 52	BAYFIELD
	035	"	PB			"	SEDIMENTARY RX		46 10 00	067 31 30	SOUTH NEWBRIDGE
	036	F				"		VEINS	46 32 40	066 38 15	MCBEAN BROOK
	037	MN	BA			"	SEDIMENTARY RX		46 34 05	066 33 45	LOWER BIRCH ISLAND
	038	F				"		VEINS	46 35 00	066 44 50	SOUTHWEST MIRAMICHI RIVER
	039	"	PB			"		"	46 35 50	066 36 15	SOUTHWEST MIRAMICHI RIVER

N T S	SEQNO		ELEMENTS			DEVELOPMENT	SYNGENETIC	EPIGENETIC	LATITUDE	LONGITUDE	NAME
NO	NO	1	2	3	4	CODE 1979	CLASSIFICATION	CLASSIFICATION			
021	040	"				"		"	46 36 00	066 39 00	SISTERS BROOK
	041	"				"		"	46 37 45	066 37 50	ROCKY BROOK
	042	W	MO	SN	F	"		"	46 39 15	066 48 45	BURNT HILL MINE
	043	CU	PB	ZN	W	"		"	46 40 00	066 34 00	CLEVELAND PROSPECT
	044	F				"		"	46 49 00	071 14 00	QUEBEC CITY
	045	ZN	PB	AG	AU	"		"	47 23 30	065 55 20	NINE MILE BROOK
	046	PYR	ZN	PB	CU	PRODUCER	SEDIMENTARY RX		47 24 30	065 19 00	BRUNSWICK NO.6-SULFIDE DEP
	047	FE	BA	ZN		OCCURRENCE		VEINS	47 24 30	065 49 25	AUSTIN BROOK IRON MINE
	048	BA	PB	CU		"		"	47 25 00	069 43 00	BEACH BARYTE PROSPECT
	049	F	PB			"		"	47 25 15	070 30 45	BAIE ST PAUL MOULIN R
	050	"				"		"	47 25 40	070 27 30	MALBAIE R CORBEAU CAPE
	051	BA				"		"	47 28 30	069 35 00	BRIAND
	052	"	PB			"		"	47 28 45	069 33 06	ST PASCAL
	053	"	PB			"		"	47 45 00	065 22 00	CLIFTON-STONEHAVEN
	054	"				"		"	47 50 30	066 01 20	MACMILLAN SETTLEMENT
	055	AG	PB	BA		"		"	47 53 51	066 09 45	NASH CREEK SILVER
	056	BA				"		"	48 00 00	064 30 00	PORT DANIEL
	057	MN	BA	CA		PAST PRODUCER			45 19 35	065 32 10	
013	001	F				OCCURRENCE	IGN INTRUS RX		54 47 00	058 24 30	TUCHIALIC BAY
	002	PB	CU	F		"		VEINS	54 50 00	058 46 30	STAG BAY
	003	MO	CU	FE	F	"	IGN INTRUS RX		55 00 30	059 03 00	BIG BIGHT
012	001	BA	GY	CU		OCCURRENCE		VEINS	48 08 00	058 58 00	SHIPS COVE
	002	SR				"		REPLACEMENT DEP	48 17 30	058 46 30	HEATHERTON SHOWING
	003	BA				"		VEINS	48 25 48	057 16 57	GLITTER POND
	004	"				"		"	48 33 00	058 38 00	ROMAINES BROOK
	005	SR	BA			DEVELOPED PROSPECT		REPLACEMENT DEP	48 33 35	058 43 55	RONAN DEPOSIT
	006	"	BA			OCCURRENCE		VEINS	48 33 45	058 46 40	GILLAMS COVE
	007	"	BA	PB	AG	"		REPLACEMENT DEP	48 33 45	058 46 42	GILLAMS COVE (W. OF)
	008	BA	PB	ZN		"		VEINS	48 34 00	058 45 00	BELLMANS COVE
	009	"				"		"	48 45 00	057 50 00	GRAND LAKE AREA
	010	ZN	PB	CU	BA	PRODUCER	IGN EXTRUS RX		48 49 00	056 52 00	BUCHANS MINE-ZONE E
012	011	F				OCCURRENCE		VEINS	50 17 00	062 48 15	JOHANN BEETZ A
	012	"				"		"	50 18 00	062 50 00	JOHANN BEETZ B
011	001	BA				OCCURRENCE		VEINS	44 49 58	063 36 17	L. FLETCHER
	002	PB	ZN	AG	BA	DEVELOPED PROSPECT		REPLACEMENT DEP	45 01 56	063 21 29	GAY"S RIVER PB-ZN DEPOSIT
	003	BA				PAST PRODUCER		"	45 14 07	063 14 01	MIDDLE STEWIACKE
	004	PB	ZN	BA		"		"	45 16 06	063 04 31	SMITHFIELD PB-ZN MINE
	005	BA				"		"	45 16 15	063 14 27	BROOKFIELD
	006	PB	ZN	BA		OCCURRENCE		"	45 17 00	062 56 30	PEMBROKE(GLENBERVIE)
	007	BA				"		VEINS	45 20 30	063 30 36	GREAT VILLAGE
	008	MN	BA			PAST PRODUCER		REPLACEMENT DEP	45 24 59	063 09 50	EAST MOUNTAIN
	009	BA				OCCURRENCE		VEINS	45 26 06	062 35 56	BRIDGEVILLE
	010	"				"		"	45 26 20	061 41 40	MELFORD
	011	"				DEVELOPED PROSPECT		REPLACEMENT DEP	45 27 48	063 46 21	BASS RIVER
	012	FE	BA			PAST PRODUCER		VEINS	45 28 40	063 36 34	ACADIA IRON MINES
	013	BA	MN			OCCURRENCE		"	45 30 30	062 40 00	BRIDGEVILLE(E R PICTOU)
	014	"	SR			"		REPLACEMENT DEP	45 32 53	061 20 33	BYERS CREEK
	015	"				"		VEINS	45 35 30	061 01 28	LENNOX FERRY
	016	"	FE			"		REPLACEMENT DEP	45 36 00	062 38 00	MELMERBY BEACH
	017	"				"		VEINS	45 36 35	062 04 07	BRIERLY BROOK
	018	"				"		"	45 37 54	063 43 49	NORTH GRENVILLE
	019	"				"		"	45 38 30	062 50 18	ROGER"S HILL
	020	CU	FE	GYP		"		"	45 40 00	060 46 00	BARRA HEAD
	021	SR				PAST PRODUCER		REPLACEMENT DEP	45 41 19	061 07 32	REAR BLACK RIVER
	022	BA				OCCURRENCE		VEINS	45 42 00	061 58 30	HALLOWELL GRANT- FAIRMOUNT
	023	"				"		"	45 43 57	063 03 09	WELSFORD
	024	PB	ZN	CU	BA	PAST PRODUCER		REPLACEMENT DEP	45 44 00	060 26 12	STIRLING(MINDAMAR) MINE
	025	BA				"		VEINS	45 44 03	062 58 09	HODSON
	026	"				OCCURRENCE		"	45 44 06	062 00 43	BIG MARSH
	027	"				"		"	45 44 21	061 53 00	MCISAAC POINT
	028	SR	PB	ZN	CU	PAST PRODUCER		REPLACEMENT DEP	45 45 00	060 32 00	KAISER CELESTITE
	029	BA				OCCURRENCE		"	45 45 30	061 53 45	CRIBBONS (CREBBING) POINT
	030	"				"		VEINS	45 45 43	062 10 21	ARISAIG AGLT QUARRY
	031	PB				"		"	45 47 00	060 36 00	LOCH LOMOND(L UIST SETT)
	032	BA				"		"	45 47 12	061 34 44	LAKEVALE
	033	"				"		REPLACEMENT DEP	45 47 45	060 37 18	LOCH LOMOND (1 MI.NW.)
	034	MN	BA			"		VEINS	45 48 45	060 30 09	MCCUISH(MOSELEY MINE)
	035	SR	BA	PB		"		"	45 49 13	063 48 53	BECKWITH(DICKSON BROOK)
	036	BA	F			"		"	45 51 25	061 25 35	JUDIQUE (CHAPEL BROOK)
	037	PB	ZN	BA	CU	"		"	45 59 02	060 57 09	LITTLE NARROWS JUBILEE
	038	BA				"		REPLACEMENT DEP	46 00 33	060 39 17	SHENACADIE
	039	SR				"		"	46 00 36	060 20 18	FRENCHVALE
	040	F	BA			PAST PRODUCER		VEINS	46 06 03	061 07 45	MACKAY-EVANS MINE
	041	BA	F			"		REPLACEMENT DEP	46 06 40	061 07 00	JOHNSON, LOWER,UPPER VEINS
	042	"	F			OCCURRENCE		VEINS	46 07 00	061 06 00	N TROUT RIVER AREA
	043	"	ZN	BA	CU	"	SEDIMENTARY RX		46 07 07	061 27 59	MABOU MINES(CUVIER PPTY)
	044	"				"		VEINS	46 07 15	061 07 55	A J MACLEAN VEIN
	045	"				"		REPLACEMENT DEP	46 07 21	062 57 48	GALLAS POINT
	046	"	F			PAST PRODUCER		VEINS	46 07 25	061 08 00	CAMPBELL MINE
	047	"	F			"		"	46 07 31	061 08 00	J A MACDOUGALL MINE

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011	048	BA	F			PAST PRODUCER		VEINS	46 07 33	061 07 50	M MACMILLAN MINE
	049	"	F			OCCURRENCE		"	46 07 37	061 07 45	D J MACDOUGALL MINE
	050	"				PAST PRODUCER		"	46 07 45	061 07 50	MOORES PIT
	051	"				OCCURRENCE		REPLACEMENT DEP	46 08 29	061 26 53	MILL BROOK(FINLAY POINT)
	052	"	CU	F	MN	"		VEINS	46 10 00	061 08 30	MACKINNON (SCOTTSVILLE)
	053	"	F			PAST PRODUCER		"	46 10 39	061 08 18	PETER CAMPBELL MINE
	054	"	F	CU	MN	"		"	46 10 40	061 08 30	SCOTSVILLE DEPOSIT
	055	F				OCCURRENCE		"	46 12 00	061 10 30	GILLIS BROOK
	056	BA	F	CU		"		"	46 41 13	060 57 45	EUSEBE POIRIER
	057	"				"		"	46 42 50	060 56 05	TROUT BR
	058	"				"		"	46 43 00	060 55 00	AMEDEE COMUS
	059	"	SR			PAST PRODUCER		"	46 43 15	060 55 51	CORNEY BROOK(CAP ROUGE)
	060	F	PB	AG	AU	OCCURRENCE		"	46 49 23	060 49 48	PLEASANT BAY
	061	"				"		"	47 24 00	059 20 24	ND
	062	BA	CA			"		"	47 51 00	059 14 00	RYANS BROOK
001	001	F	BA	PB	ZN	PAST PRODUCER		VEINS	46 52 33	055 24 30	LORD AND LADY GULCH MINE
	002	"	CU	PB		OCCURRENCE		"	46 52 36	055 23 40	RED HEAD VEIN
	003	"	PB	ZN	AG	"		"	46 52 36	055 26 06	CHAMBERS COVE
	004	"	BA			PAST PRODUCER		"	46 52 39	055 26 00	LITTLE SALT COVE BROOK
	005	"				OCCURRENCE		REPLACEMENT DEP	46 52 40	055 28 30	SPICES COVE(LAWN HEAD)
	006	"				"		VEINS	46 52 42	055 28 42	LAWN HEAD
	007	"	BA	CU	PB	"		"	46 52 45	055 25 15	SALT COVE VEIN
	008	"				DEVELOPED PROSPECT		"	46 52 45	055 25 30	TAREFARE SHORE
	009	"	BA	PB	CU	OCCURRENCE		"	46 52 50	055 26 00	LEAD VEIN
	010	"				"		"	46 53 00	055 24 00	SHOAL COVE POND
	011	"	BA			DEVELOPED PROSPECT		"	46 53 00	055 25 00	BARITE FAULT
	012	"				OCCURRENCE		"	46 53 03	055 22 54	DEADMANS COVE VEIN
	013	"				"		"	46 53 10	055 25 40	GRASSY GULCH VEIN
	014	"	BA	PB	ZN	"		"	46 53 15	055 25 30	ALBERT BECK VEIN
	015	"	MN			"		"	46 53 20	055 22 51	CHAPEAU ROUGE VEIN
	016	"				PAST PRODUCER		"	46 53 20	055 25 18	IRON SPRINGS-W.EXTENSION M
	017	"	CU	PB		"		"	46 53 24	055 24 42	HARES EARS VEIN
	018	"				"		"	46 53 24	055 25 52	BLOWOUT VEIN
	019	"				"		"	46 53 30	055 25 45	CROSS VEIN-TAREFARE MINE
	020	"				"		"	46 53 30	055 25 45	HOPE VEIN
	021	"	BA	CU	PB	"		"	46 53 48	055 26 06	TAREFARE MINE
	022	"				"		"	46 54 15	055 25 15	DIRECTOR MINE
	023	"	BA	CU	PB	"		"	46 54 18	055 23 24	BLUEBEACH VEIN
	024	"				OCCURRENCE		"	46 54 20	055 25 00	CANAL VEIN
	025	"	PB	ZN	CU	"		"	46 54 20	055 26 00	BLAKES BROOK VEINS
	026	BA	CU			"		"	46 54 20	055 34 06	RAGGED HEAD
	027	"				"		"	46 54 30	055 19 30	MIDDLE BIGHT COVE
	028	F				"		"	46 54 30	055 23 12	ISLAND ROCK VEIN
	029	"				"		"	46 54 36	055 22 35	HERRING COVE VEIN
	030	"				"		"	46 54 45	055 25 00	QUICK WOOD VEIN
	031	"	PB	ZN	CU	PAST PRODUCER		"	46 54 45	055 28 42	GREBES NEST VEIN
	032	"				OCCURRENCE		"	46 55 00	055 23 10	RED ROBIN-MORRIS LEASES
	033	"				PAST PRODUCER		"	46 55 00	055 24 45	BLUE BEACH NO 3
	034	"				OCCURRENCE		"	46 55 00	055 25 00	HAYPOOK POND VEIN
001	035	F	BA	PB		DEVELOPED PROSPECT		VEINS	46 55 00	055 25 48	VALLEY VEIN
	036	"	PB	ZN	AG	OCCURRENCE		"	46 55 18	055 28 54	MINE COVE
	037	"	BA	CU	PB	"		"	46 55 15	055 25 40	SOUTHERN CROSS VEINS
	038	"	PB			"		"	46 55 25	055 23 15	CHURCH VEIN-MORRIS LEASES
	039	"				"		"	46 55 28	055 25 00	HOOKEY BRANCH VEIN
	040	"				PAST PRODUCER		"	46 55 30	055 22 35	SCRAPE VEIN
	041	"				OCCURRENCE		"	46 55 39	055 25 06	LAWN ROAD VEINS
	042	"				PAST PRODUCER		"	46 55 40	055 22 40	DOCTORS POND VEINS
	043	"				OCCURRENCE		"	46 55 40	055 24 40	BOXHEATER VEIN
	044	"				"		"	46 55 45	055 23 48	NEW BLACK DUCK VEIN
	045	"				PAST PRODUCER		"	46 56 00	055 23 20	BLACK DUCK MINE
	046	"				OCCURRENCE		"	46 56 09	055 25 00	CRANBERRY BOG
	047	BA				"		"	46 56 18	054 11 30	CROSS POINT
	048	"				"		"	46 56 30	054 10 56	PERCH COVE
	049	F	CU			"		"	46 56 30	055 32 00	LAWN
	050	"				"		"	46 56 48	054 23 33	RYAN"S HILL VEIN
	051	"				"		"	46 56 51	055 23 24	SALMON HOLE
	052	BA				"		"	46 57 30	054 10 13	CUSLETT COVE S SIDE
	053	F				"	SEDIMENTARY RX		46 57 33	055 21 42	MOUNT MARGARET SPAR FLOAT
	054	BA				"		VEINS	46 58 00	054 10 18	OTTERRUB VEIN
	055	F	BA			"		"	46 58 33	055 23 00	CLAM POND
	056	"	BA	PB		"		"	46 59 15	055 31 00	BIG MEADOWS VEIN
	057	"	BA	PB		DEVELOPED PROSPECT		"	46 59 24	055 31 30	MEADOW WOODS VEIN
	058	"				OCCURRENCE		"	47 00 23	055 22 48	SHATTER CLIFF
	059	"	BA			"		"	47 01 00	055 18 00	ROCKY POND
	060	"				"		"	47 01 30	055 24 36	TILT HILL
	061	"	BA			"		"	47 03 25	055 25 00	SHARP PEAK
	062	"	BA			"		"	47 04 25	055 14 39	ANCHOR DROGUE
	063	"	BA	PB		"		"	47 04 27	055 17 30	SHEARSTICK BROOK
	064	BA				"		"	47 06 00	055 22 00	DEVIL"S KITCHEN
	065	F				"		"	47 06 00	055 45 00	GRAND BEACH
	066	"	BA	PB		"		"	47 10 00	055 26 18	LUNCH POND CLAIM
	067	BA	CU			"		"	47 17 15	054 49 35	ODERIN ISL
	068	PB	ZN	AG	AU	PAST PRODUCER		"	47 18 06	053 56 48	SILVER CLIFF MINE
	069	F				OCCURRENCE		"	47 25 48	053 58 36	HARBOUR ISL. (SE COAST)
	070	MN	BA			"	SEDIMENTARY RX		47 29 30	052 56 00	MANUELS-TOPSAIL AREA
	071	F				"		VEINS	47 32 00	054 52 00	BERRY HILL
	072	BA				PAST PRODUCER		"	47 35 30	053 41 24	COLLIER COVE
	073	F				OCCURRENCE		"	47 35 30	055 05 00	LONG HARBOUR

N T S NO	SEQNO NO	ELEMENTS 1	2	3	4	DEVELOPMENT CODE 1979	SYNGENETIC CLASSIFICATION	EPIGENETIC CLASSIFICATION	LATITUDE	LONGITUDE	NAME
001	074	"				"		"	47 35 54	055 00 36	FEMME HARBOUR
	075	"				"		"	47 36 00	055 05 00	STROUDS HILL (OLD BALDY)
	076	BA				"		"	47 36 00	053 50 24	DOE HILLS
	077	"				"		"	47 36 57	054 50 48	CAPE MILLE
	078	"	F			"		"	47 37 30	054 53 00	ENGLISH HARBOUR EAST W.SID
	079	MO	CU	F	BA	"		"	47 38 00	055 21 00	BELLE ISLAND
	080	BA				"		"	47 39 30	053 43 30	BELLEVUE
	081	"				"		"	47 39 32	053 42 24	BELLEVUE (BELLEVUE PEN.W.)
	082	"				"		"	47 39 36	053 43 30	TICKLE BAY (E. SIDE)
	083	"				"		"	47 40 27	053 53 06	SERRATED HILLS
	084	"				"		"	47 41 16	053 41 06	TICKLE HARBOUR PT.
	085	PB	ZN	CU	BA	PAST PRODUCER		"	47 41 30	053 57 00	LA MANCHE MINE
	086	BA				OCCURRENCE		VEINS	47 41 45	053 54 48	SUTTON SHOWING
	087	F	BA			"		"	47 41 50	054 53 00	EASTERN LOOKOUT
	088	BA				"		"	47 42 30	053 52 00	RANTEM COVE
	089	PB	ZN	BA	CU	"		"	47 48 00	055 51 25	ROTI POINT

Table 33. Alphabetical index to Canadian barium-strontium- and fluorine-bearing occurrences

NAME	QUADRANGLE NUMBER	SEQUENCE NUMBER	POLITICAL PROVINCE	TECTONIC PROVINCE	TECTONIC SUBPROVINCE
ACADIA IRON MINES	011	012	N.S.	APPALACHIAN OROGEN	CAPE SPLIT BASIN
ACHOOK IS	086	004	N.W.T.	BEAR PROVINCE	
AILPORT PROSPECT(JOKER)	093	009	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
ALASKA HWY MI 397-110 CR	094	010	-	-	EASTERN FOLD BELT
ALASKA HWY MI 472	-	015	-	-	ROCKY MTN THRUST BELT
ALBERT BECK VEIN	001	014	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
ALGOMA MINE	052	049	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
ALICE WILDA BETTY GREEN	082	004	B.C.	CORDILLERAN OROGEN	ROCKY MTN THRUST BELT
ALMA(MYRTLE) GRP	-	023	-	-	OMINECA CRYSTALLINE BELT
AMEDEE COMUS	011	050	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT NE
AMHERSTBURG	040	001	ONT.	ST. LAWRENCE PLATFORM	ALGONQUIN ARCH
ANCHOR DROGUE	001	062	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
ANDERSON-BINGHAM PPTY	052	083	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
ANDERSON VEIN	-	070	-	-	-
ANNA GRP	082	019	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT NE
ANNIE LAURIE CL	103	001	-	-	COAST CRYSTALLINE BELT
ANSE-A-LA CAVE	022	001	QUE.	GRENVILLE PROVINCE	BAIE COMEAU BELT
APEX(ROAD SHOWING)	093	010	B.C.	CORDILLERAN OROGEN	COLUMBIA INTRMNT NE
ARISAIG AGLT QUARRY	011	030	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
ARIZONA CR	115	007	Y.T.	ST. LAWRENCE PLATFORM	EASTERN FOLD BELT NE
ARSENO GRP	085	005	N.W.T.	SLAVE PROVINCE	
ART EKWI N	105	033	-	CORDILLERAN OROGEN	MACKENZIE FOLD BELT NE
ART EKWI S	-	030	-	-	MACKENZIE FOLD BELT
ATAN-AUGUST CL GRPS	104	017	B.C.	-	OMINECA CRYSTALLINE BELT
AUGUSTA MINE	052	011	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
ALMOND TP	031	139	QUE.	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
AUSTIN BROOK IRON MINE	021	047	N.B.	APPALACHIAN OROGEN	NEW BRUNSWICK HIGHLANDS
A J MACLEAN VEIN	011	044	N.S.	-	MARITIME FOLD BELT
BAIE ST PAUL MOULIN R	021	049	QUE.	GRENVILLE PROVINCE	
BAILEY MINE	031	029	ONT.	-	
BARITE FAULT	001	011	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
BARITE GOLD MINES LTD	104	005	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
BARRA HEAD	011	020	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
BARRIE	031	067	ONT.	GRENVILLE PROVINCE	
BAR PROSPECT	105	026	Y.T.	CORDILLERAN OROGEN	SELWYN FOLD BELT
BASIN DEPOSIT	031	077	ONT.	GRENVILLE PROVINCE	
BASS RIVER	011	011	N.S.	APPALACHIAN OROGEN	CAPE SPLIT BASIN
BATHURST STA	031	069	ONT.	GRENVILLE PROVINCE	
BAYFIELD	021	034	N.B.	APPALACHIAN OROGEN	MARITIME FOLD BELT
BA CLAIMS	105	029	N.W.T.	CORDILLERAN OROGEN	MACKENZIE FOLD BELT
BEACH BARYTE PROSPECT	021	048	QUE.	APPALACHIAN OROGEN	QUEBEC ANTICLINORIUM
BEAUCHASTEL L	032	004	-	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
BEAVER JR	052	034	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
BEAVER MINE(ML T97)	-	031	-	-	-
BECKWITH(DICKSON BROOK)	011	035	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
BECK MINE	052	060	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
BEECH HILL	021	032	N.B.	APPALACHIAN OROGEN	MARITIME FOLD BELT
BELLEKENO MINE	105	031	Y.T.	CORDILLERAN OROGEN	EASTERN FOLD BELT NE
BELLEVUE (BELLEVUE PEN.W.)	001	001	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
BELLEVUE	001	080	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
BELLE ISLAND	-	079	-	-	-
BELLMANS COVE	012	008	-	-	WESTERN PLATFORM
BERREA	031	111	QUE.	GRENVILLE PROVINCE	
BERRY HILL	001	071	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
BEVERLY GROUP	094	004	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT E
BIEDERMAN CLAIM	042	001	ONT.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
BIG BEAR VEIN	052	035	-	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
BIG BIGHT	013	003	NFLD.	CHURCHILL PROVINCE	MAKKOVIK FOLD BELT
BIG MARSH	011	026	N.S.	APPALACHIAN OROGEN	CAPE SPLIT BASIN
BIG MEADOWS VEIN	001	056	NFLD.	-	AVALON PLATFORM
BIG SPRUCE LAKE	085	006	N.W.T.	SLAVE PROVINCE	
BIG TROUT BAY	052	001	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
BISHOP CLS 5-6L	-	005	-	-	-
BLACKBURN MINE	031	121	QUE.	GRENVILLE PROVINCE	
BLACK DUCK MINE	001	045	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
BLACK HILL EXCELSIOR GRP	103	018	B.C.	CORDILLERAN OROGEN	COAST CRYSTALLINE BELT
BLACK R FALLS	042	010	ONT.	SUPERIOR PROVINCE	WAWA BELT
BLACK (BROCK) RIVER	021	023	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
BLAKELEY MINE	031	013	ONT.	ST. LAWRENCE PLATFORM	OTTAWA EMBAYMENT
BLAKES BROOK VEINS	001	025	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
BLENDE LAKE VEIN	052	067	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
BLOCK B CLS	032	006	QUE.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
BLOCK F	-	009	-	-	-
BLOWOUT VEIN	001	018	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
BLUEBEACH VEIN	-	023	-	-	-
BLUE BEACH NO 3	-	033	-	-	-
BLUE LIGHT	104	019	B.C.	CORDILLERAN OROGEN	CASSIAR BELT
BNOB	105	040	Y.T.	-	
BONANZA GRP-DOWDELL POINT	086	002	N.W.T.	BEAR PROVINCE	GREAT BEAR BATHOLITH
BONANZA (PRINCE GEORGE)	093	004	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT
BOTTING OCCURRENCE	031	020	ONT.	GRENVILLE PROVINCE	FRONTENAC ARCH
BOURLAMAQUE TP	032	001	QUE.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
BOURRET SHOWING	031	117	-	GRENVILLE PROVINCE	
BOXHEATER VEIN	001	043	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
BOYER	031	137	QUE.	GRENVILLE PROVINCE	QUEBEC GNEISS BELT
BRANDY BROOK	022	006	-	APPALACHIAN OROGEN	GASPE SYNCLINORIUM
BRIAND	021	051	-	-	QUEBEC ANTICLINORIUM
BRIDGEVILLE(E R PICTOU)	011	013	N.S.	-	MARITIME FOLD BELT E

NAME	QUADRANGLE NUMBER	SEQUENCE NUMBER	POLITICAL PROVINCE	TECTONIC PROVINCE	TECTONIC SUBPROVINCE
BRIDGEVILLE	-	009	-	-	MARITIME FOLD BELT
BRIERLY BROOK	-	017	-	-	CAPE SPLIT BASIN
BRISCO SALMON WAMINECA CLS	082	042	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT
BRITANNIA MINE BLUFF	092	007	-	-	COAST PLUTONIC COPPLEX
BRITANNIA MINE FAIRVIEW	-	005	-	-	-
BRITANNIA MINE JANE	-	006	-	-	-
BRODIE QUARRY	031	140	QUE.	GRENVILLE PROVINCE	
BROOKBANK PPTY	042	002	ONT.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
BROOKFIELD	011	005	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
BRUCE COPPER MINES	041	003	ONT.	SOUTHERN PROVINCE	PENCKEAN FOLD BELT
BRUNSWICK NO.6-SULFIDE DEP	021	046	N.B.	APPALACHIAN OROGEN	MIRAMACHI ANTICLINORIUM
BUCHANS MINE-ZONE E	012	010	NFLD.	-	CENTRAL MOBILE BELT NE
BUCK GROUP	093	007	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
BUCK ISLAND	052	062	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
BUELL(LANSDOWNE)	031	040	-	GRENVILLE PROVINCE	GRENVILLE GRP BELT
BUGABOO VOWELL FORSTER CRS	082	040	B.C.	CORDILLERAN OROGEN	
BULL MOOSE CLAIM	085	002	N.W.T.	CHURCHILL PROVINCE	EAST ARM FOLD BELT
BURNT HILL MINE	021	042	N.B.	APPALACHIAN OROGEN	FREDERICTON SYNCLINORIUM
BURN(1-20)	094	005	B.C.	CORDILLERAN OROGEN	WANA BELT
BURRIDGE RD	031	055	ONT.	GRENVILLE PROVINCE	
BUTTERILL	-	053	-	-	
BYERS CREEK	011	014	N.S.	APPALACHIAN OROGEN	ONTARI
CALUMET-HECLA GRP	082	018	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
CALUMET CONTACT U MINES	031	127	QUE.	GRENVILLE PROVINCE	
CALUMET URANIUM ML	-	128	-	-	
CAMERON TP	-	136	ONT.	-	ONTARIO GNEISS BELT
CAMPBELL MINE	011	046	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
CAMPBELL SHOWING	031	096	ONT.	GRENVILLE PROVINCE	
CAMPBELL TP	-	138	QUE.	-	
CAMPOBELLO ISLAND	021	005	N.B.	APPALACHIAN OROGEN	MARITIME FOLD BELT
CAMP CLIFF NICK BAR	094	017	B.C.	CORDILLERAN OROGEN	MACKENZIE FOLD BELT
CANADA RADIUM	031	072	ONT.	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
CANADA TUNGSTEN MINE	105	012	N.W.T.	CORDILLERAN OROGEN	MACKENZIE FOLD BELT
CANADIAN BERYLLIUM	031	090	ONT.	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
CANADIAN MALARTIC GML	032	002	QUE.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
CANAL VEIN	001	024	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
CAPE MILLE	-	077	-	-	-
CAPE ROBERT	041	002	ONT.	ST. LAWRENCE PLATFORM	ALGONQUIN ARCH
CARDIFF TP	031	083	-	GRENVILLE PROVINCE	ONTARIO GNEISS BELT NE
CARDIFF U MINE A E ZONES	-	075	-	-	GRENVILLE BELT
CARDIFF U MINE B-C ZONES	-	073	-	-	ONTARIO GNEISS BELT
CARIBOU-CHIEFTAIN HILLS	105	007	Y.T.	CORDILLERAN OROGEN	INTERMONTANE BELT W
CARLICK GRP - ATAN LAKE	104	018	B.C.	-	OMINECA CRYSTALLINE BELT
CASEY CAMP	103	007	-		
CASEY HILL	031	091	ONT.	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
CASHEL TP	-	070	-	-	-
CASINO CREEK	115	006	Y.T.	CORDILLERAN OROGEN	YUKON CRYSTALINE PLATFORM
CATHY-BAROID	105	034	-	-	
CHAMBERS COVE	001	003	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
CHAPEAU ROUGE VEIN	-	015	-	-	-
CHENEY MINE	041	004	ONT.	SOUTHERN PROVINCE	PENOKEAN FOLD BELT
CHEVERIE CLIFFS	021	009	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
CHRYSLER LEAD PPTY	031	060	ONT.	GRENVILLE PROVINCE	
CHURCH VEIN-MORRIS LEASES	001	038	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
CHZERPHOUGH	105	039	Y.T.	CORDILLERAN OROGEN	ROCKY MTN THRUST BELT
CLAM POND	001	055	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
CIRQUE	094	026	B.C.	CORDOLLERAN OROGEN	ROCKY MTN THRUST BELT
CLAREMONT GROUP	092	008	-	CORDILLERAN OROGEN	INTERMONTANE BELT W
CLARK PPTY	031	004	ONT.	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
CLEVELAND PROSPECT	021	043	N.B.	APPALACHIAN OROGEN	FUNDY SUCCESSOR BASIN
CLIFTON-STONEHAVEN	-	053	-	-	MARITIME PLAIN
CLIMAX GRP	103	017	B.C.	CORDILLERAN OROGEN	COAST CRYSTALLINE BELT
CLIMAX KEYSTONE MINE	052	030	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
CLYDE FORKS	031	005	-	GRENVILLE PROVINCE	GRENVILLE BELT
CLYDE SMITH CLS	105	020	Y.T.	CORDILLERAN OROGEN	SELWYN FOLD BELT
COBALT GRP ELDORADO MINE	086	003	N.W.T.	BEAR PROVINCE	GREAT BEAR PLUTON W
CORDEN	031	123	ONT.	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
COE PPTY	-	010	-	-	
COLE MINE	-	120	-	-	ONTARIO GNEISS BELT
COLLIER COVE	001	072	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
COOK COPPER AND FLUORITE	032	003	QUE.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
COPPER KING IMPERIAL	082	035	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT
CORAL(LIARD CROSSING)	094	018	-	-	MACKENZIE FOLD BELT
CORNEY BROOK(CAP ROUGE)	011	059	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
CRANBERRY BOG	001	046	NFLD.	-	AVALON PLATFORM
CREDIT FORKS	030	001	ONT.	ST. LAWRENCE PLATFORM	ALGONCUIN ARCH
CRESWEL(BADGER MINE)	052	026	-	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
CRESWEL(PORCUPINE MINE)	-	025	-	-	-
CRESWEL(SILVER CR MINE)	-	029	-	-	-
CRIBBONS (CREBRING) POINT	011	029	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
CROSS POINT	001	047	NFLD.	-	AVALON PLATFORM
CROSS VEIN-TAREFARE MINE	-	019	-	-	-
CROWN KING LEAD PROSPECT	031	060	ONT.	GRENVILLE PROVINCE	LAURENTIAN HIGHLANDS
CROWN POINT MINE	052	015	-	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
CRYDERMAN (RAVENA) PROP	042	003	-	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
CTV CBC HOPE DODO	094	009	B.C.	CORDILLERAN OROGEN	ROCKY MTN THRUST BELT
CUMBERLAND GR. MOUNT MADGE	104	010	-	-	INTERMONTANE BELT W
CUPRA MINE	021	029	QUE.	APPALACHIAN OROGEN	QUEBEC ANTICLINORIUM E
CUSLETT COVE S SIDE	001	052	NFLD.	-	AVALON PLATFORM
CYPRESS LAKE	072	001	SASK.	INTERIOR PLATFORM	WILLISTON BASIN

NAME	QUADRANGLE NUMBER	SEQUENCE NUMBER	POLITICAL PROVINCE	TECTONIC PROVINCE	TECTONIC SUBPROVINCE
DALVENIE(BIG CHIEF)	104	012	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
DAVID COPPERFIELD GRP.	103	012	"	"	COAST CRYSTALLINE BELT
DAVIES CLAIMS	094	003	"	"	OMINECA CRYSTALLINE BELT
DEADMANS COVE VEIN	001	012	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
DERRY TP	031	130	QUE.	GRENVILLE PROVINCE	
DESOLATION CREEK S	082	002	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT
DETROIT-ALGOMA MINE	052	075	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
DEVILS WAREHOUSE IS	041	008	"	SUPERIOR PROVINCE	KAPUSKASING FAULT ZONE
DEVIL"S KITCHEN	001	064	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
DINGO GROUP	086	001	N.W.T.	SLAVE PROVINCE	
DIRECTOR MINE	001	022	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
DOCTORS POND VEINS	"	042	"	"	"
DOE HILLS	"	076	"	"	"
DOG LAKE	031	006	ONT.	GRENVILLE PROVINCE	
DOLLY VARDEN MINE-WOLF GRP	103	013	B.C.	CORDILLERAN OROGEN	COAST CRYSTALLINE COMPLEX
DORCHESTER(DORBECK)	021	031	N.B.	APPALACHIAN OROGEN	MARITIME FOLD BELT
DORION MINE	052	084	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
DORSEY SHOWING	105	004	Y.T.	CORDILLERAN OROGEN	CASSIAR BELT
DRIFTPILE CREEK	094	024	B.C.	"	ROCKY MTN THRUST BELT
DWYER PPTY	031	082	ONT.	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
D J MACDOUGALL MINE	011	049	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
EAGLET FLUORITE	093	002	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
EAGLE CLAIMS	052	101	MAN.	SUPERIOR PROVINCE	
EARLY BIRD CLAIM	082	013	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
EASTERN LOOKOUT	001	087	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
EAST MOUNTAIN	011	008	N.S.	"	MARITIME FOLD BELT
EAST R OF FIVE ISLANDS	021	020	"	"	MARITIME FOLD BELT NE
EBY OR SCOTT CL	041	011	ONT.	SOUTHERN PROVINCE	COBALT EMBAYMENT
EDGAR LAKE AREA	024	001	QUE.	CHURCHILL PROVINCE	DORSET FOLD BELT
EDWARD ISLAND	052	044	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
EGG FOO	094	008	B.C.	CORDILLERAN OROGEN	ROCKY MTN THRUST BELT
ELF	"	027	"	"	"
ELGIN VEIN	052	036	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
EL PASO GRP	092	009	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT
EMERALD MINE	082	005	"	"	OMINECA CRYSTALLINE BELT
EMMONS HILL PPTY	115	005	Y.T.	"	COAST CRYSTALLINE BELT
ENGINEER CLAIM	103	003	B.C.	"	"
ENGLISH HARBOUR EAST W.SID	001	078	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
ENTERPRISE MINE	052	074	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
EUREKA(DUNCAN MINE)	021	019	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT NE
EUSEBE POIRIER	011	056	"	"	"
EVENING SUN CLAIM	103	019	B.C.	CORDILLERAN OROGEN	COAST CRYSTALLINE BELT
EVERGREEN CLAIMS	093	011	"	"	OMINECA CRYSTALLINE BELT
EXTENDER MINERALS	041	007	ONT.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
E OF WOLF LAKE	105	008	Y.T.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
FARADAY U MINE	031	074	ONT.	GRENVILLE PROVINCE	GRENVILLE GRP BELT
FARO- NO1 AND 2	"	015	Y.T.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
FARRELL PPTY	031	063	ONT.	GRENVILLE PROVINCE	
FEDERAL MINE COPELAND VEIN	052	040	"	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
FEMME HARBOUR	001	074	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
FENSTER CR N	082	007	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT
FENSTER CR S	"	006	"	"	"
FEUCHTWANGER PPTY	021	012	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
FIDDLER YUKON MINE	105	005	Y.T.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
FIRESAND R CARBONATITE	041	012	ONT.	SUPERIOR PROVINCE	WAWA BELT
FIRE(LIARD CROSSING)	094	019	B.C.	CORDILLERAN OROGEN	MACKENZIE FOLD BELT
FIVE MILE POINT	082	038	"	"	OMINECA CRYSTALLINE BELT
FLEMING-PORTER CLS	105	006	Y.T.	"	COAST CRYSTALLINE BELT
FLORENCE R G M	032	012	QUE.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
FLUKE	094	028	B.C.	CORDILLERAN OROGEN	ROCKY MTN THRUST BELT
FOLEY MINE	031	106	QUE.	GRENVILLE PROVINCE	
FOX GROUP(OAK R)	103	010	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
FOX GRP	"	009	"	"	COAST CRYSTALLINE BELT
FRAZER DUNTILE QUARRY	031	093	ONT.	ST. LAWRENCE PLATFORM	
FRENCHVALE	011	039	N.S.	APPALACHIAN OROGEN	
FRONTENAC LEAD MINE	031	009	ONT.	GRENVILLE PROVINCE	GRENVILLE GRP BELT
FRONTENAC QUARRY	"	001	"	ST. LAWRENCE PLATFORM	
FRYE ISLAND	021	006	N.B.	APPALACHIAN OROGEN	MARITIME FOLD BELT NE
GALENA FARM MINE CURRIE GR	082	027	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
GALLAS POINT	011	045	P.E.I.	APPALACHIAN OROGEN	FUNDY EPIEUGEOSYNCLINE
GARY	105	034	Y.T.	CORDILLERAN OROGEN	SELWYN FOLD BELT
GAY"S RIVER PB-ZN DEPCSIT	011	002	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
GEM(LIARD CROSSING)	094	016	B.C.	CORDILLERAN OROGEN	MACKENZIE FOLD BELT
GEORGE COPPER GROUP	104	002	"	"	INTERMONTANE BELT W
GILLAMS COVE (W. OF)	012	007	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
GILLAMS COVE	"	006	"	"	"
GILLIS BROOK	011	055	N.S.	"	MARITIME FOLD BELT
GK	105	043	Y.T.	CORDILLERAN OROGEN	ROCKY MTN THRUST BELT
GLEN (LUCY NO.1 CLAIMS)	052	094	MAN.	SUPERIOR PROVINCE	
GLITTER POND	012	003	NFLD.	APPALACHIAN OROGEN	CENTRAL MOBILE BELT
GOLD DROP CLAIM	082	011	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
GOODMORNING LAKE	052	081	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
GORDON CLS	094	001	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT
GORDON CL 6038	052	091	ONT.	SOUTHERN PROVINCE	

NAME	QUADRANGLE NUMBER	SEQUENCE NUMBER	POLITICAL PROVINCE	TECTONIC PROVINCE	TECTONIC SUBPROVINCE
GORMAN PPTY-ANGERS STA	031	114	QUE.	GRENVILLE PROVINCE	
GOSHEN MINE	021	010	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
GOYETTE-SUP PROPERTY	032	010	QUE.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
GRAND BEACH	001	065	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
GRAND FORKS	115	008	Y.T.	CORDILLERAN OROGEN	YUKON CRYSTALLINE PLATFRM
GRAND LAKE AREA	012	009	NFLD.	APPALACHIAN OROGEN	NOTRE DAME BELT
GRAND MANAN IS	021	001	N.B.	-	MARITIME FOLD BELT
GRASSY GULCH VEIN	001	013	NFLD.	-	AVALON PLATFORM
GREAT VILLAGE	011	007	N.S.	-	MARITIME FOLD BELT E
GREBES NEST VEIN	001	031	NFLD.	-	AVALON PLATFORM
GRUM	105	037	Y.T.	CORDILLERAN OROGEN	SELWYN FOLD BELT
GUNN CLAIMS	-	017	-	-	-
GUNTER	031	071	ONT.	GRENVILLE PROVINCE	
HALLOWELL GRANT- FAIRMOUNT	011	022	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
HARBOUR ISL. (SE COAST)	001	069	NFLD.	-	AVALON PLATFORM
HARES EARS VEIN	-	017	-	-	-
HARVEY CL NO. 10285	041	016	ONT.	SOUTHERN PROVINCE	COBALT EMBAYMENT
HARVEY STA	021	026	N.B.	APPALACHIAN OROGEN	FREDERICTON SYNCLINE
HASBALA LAKE	064	001	MAN.	CHURCHILL PROVINCE	
HAWKSBURY	031	112	ONT.	ST. LAWRENCE PLATFORM	OTTAWA EMBAYMENT
HAYCOCK MINE	-	110	QUE.	GRENVILLE PROVINCE	
HAYPOOK POND VEIN	001	034	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
HEATHERTON SHOWING	012	002	-	-	WESTERN PLATFORM
HERRINGTON SOUTH	031	007	ONT.	GRENVILLE PROVINCE	
HERRINGTON	-	023	-	ST. LAWRENCE PLATFORM	FRONTENAC ARCH
HERRING COVE VEIN	001	029	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
HESS MTS	105	036		CORDILLERAN OROGEN	
HEWITSON QUARRY	052	051	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE E
HIDDEN TREASURE MINE	-	010	-	-	PORT ARTHUR HOMOCLINE
HIGHLANDER(HIGHLAND MINE)	082	017	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
HIGHLAND GRP.	103	008	B.C.	CORDILLERAN OROGEN	COAST CRYSTALLINE BELT
HIGHLAND LIGHT	-	026	-	-	OMINECA CRYSTALLINE BELT
HILL PPTY	031	037	ONT.	GRENVILLE PROVINCE	GRENVILLE TYPE BELT
HODSON	011	025	N.S.	APPALACHIAN OROGEN	CAPE SPLIT BASIN
HOLLANDIA LEAD MINE	031	057	ONT.	GRENVILLE PROVINCE	LAURENTIAN HIGHLANDS
HOMEBUSH CLMS	103	011	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
HOMESTAKE GRP	082	045	-	-	-
HOOKEY BRANCH VEIN	001	039	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
HOPE VEIN	-	020	-	-	-
HORSEFLY PLACER	093	001	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
HOWARD(HILL)	031	010	ONT.	ST. LAWRENCE PLATFORM	
HOWES PROSPECT	-	044	-	GRENVILLE PROVINCE	
HULL TP	-	109	QUE.	-	
HUNKER GERMAINE CR PLACERS	116	001	Y.T.	CORDILLERAN OROGEN	YUKON CRYSTALLINE PLATFRM
HUNTINGDON	031	035	ONT.	GRENVILLE PROVINCEORM	
HYMER"S VEIN	052	021	-	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
INDEPENDENCE GOLD	104	001	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
IRONSIDE MINE	031	100	QUE.	GRENVILLE PROVINCE	
IRON ISLAND	-	135	ONT.	-	ONTARIO GNEISS BELT
IRON SPRINGS-N.EXTENSION M	001	016	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
ISLAND ROCK VEIN	-	028	-	-	-
ISL. IN THIRD CRANBERRY L.	063	001	MAN.	CHURCHILL PROVINCE	FLIN FLON FOLD BELT
IT IN TO(RUDDOCK CR)	082	052	B.C.	CORDILLERAN OROGEN	OMINECA BELT
JAMES MURPHY	031	050	ONT.	GRENVILLE PROVINCE	
JAROUN MINE	041	005	-	SOUTHERN PROVINCE	LAKE SUPERIOR BASIN
JARVIS ISLAND	052	003	-	-	PORT ARTHUR HOMOCLINE
JASON CLAIMS	105	022	Y.T.	CORDILLERAN OROGEN	SELWYN FOLD BELT
JOHANN BEETZ A	012	011	QUE.	GRENVILLE PROVINCE	BAIE COMEAU BELT
JOHANN BEETZ B	-	012	-	-	-
JOHNSON MINE	031	011	ONT.	ST. LAWRENCE PLATFORM	
JOHNSON, LOWER,UPPER VEINS	011	041	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
JOHNSTON SHOWING	052	072	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
JOHNSTON	031	118	-	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
JOHN CAMERON	041	014	-	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
JOHN CRAWFORD II	031	066	-	GRENVILLE PROVINCE	
JOHN CRAWFORD I	-	064	-	-	
JOHN MURPHY	-	048	-	-	
JOHN PPTY	052	047	-	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
JONES PPTY	-	045	-	-	-
JONES	031	004	-	ST. LAWRENCE PLATFORM	FRONTENAC ARCH
JUDIQUE (CHAPEL BROOK)	011	036	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
JUNE, SILVER TIP, ALL BLUE	082	025	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
J A MACDOUGALL MINE	011	047	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
KAISER CELESTITE	011	020	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
KAMINISTIKWIA R	052	039	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE

NAME	QUADRANGLE NUMBER	SEQUENCE NUMBER	POLITICAL PROVINCE	TECTONIC PROVINCE	TECTONIC SUBPROVINCE
KARIES CLAIM	052	076	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
KATHERINE LEAD MINES	031	058	-	GRENVILLE PROVINCE	
KEENE PPTY	-	027	-	-	
KELLOW PPTY(ML42)	052	050	-	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
KEMERER PPTY	-	078	-	-	-
KEN CLAIMS	106	003	Y.T.	CORDILLERAN OROGEN	MACKENZIE FOLD BELT
KILPATRICK (DETOMAC)	031	024	ONT.	GRENVILLE PROVINCE	FRONTENAC ARCH
KINBURN	-	144	-	-	
KINGDON OR GALETTA PB MINE	-	095	-	-	LAURENTIAN HIGHLANDS
KLUANE L	115	001	Y.T.	CORDILLERAN OROGEN	ST ELIAS FOLD BELT
KOBUK	105	035	N.S.	-	SELWYN FOLD BELT
KNOBEL PT	052	065	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
KOOTENAY FLORENCE	082	012	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
LACORNE MINE	032	007	QUE.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
LACORNE TP	032	008	-	-	-
LAKEVALE	011	032	N.S.	APPALACHIAN OROGEN	CAPE SPLIT BASIN
LAKE SHORE GOLD MINE	042	004	ONT.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
LAMBERT ISLAND	052	064	-	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
LARRABEE PPTY	082	037	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT W
LAST CHANCE GRP.	103	005	-	-	COAST CRYSTALLINE BELT
LAST MOUNTAIN (2.8 MI.NW)	095	004	N.W.T.	-	MACKENZIE FOLD BELT
LAST MOUNTAIN (4.4MI.NW)	-	005	-	-	-
LAST MTN	-	003	Y.T.	-	EASTERN FOLD BELT
LAWN HEAD	001	006	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
LAWN ROAD VEINS	-	041	-	-	-
LAWN	-	049	-	-	-
LAWSON TP	041	009	QUE.	SUPERIOR SUBPROVINCE	ABITIBI VOLCANIC BELT
LA MANCHE MINE	001	005	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
LEADVILLE GRP.(LUCKY TODD)	092	010	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
LEAD VEIN	001	009	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
LEBEL PPTY	052	006	ONT.	SOUTHERN PROVINCE	LAKE SUPERIOR BASIN NE
LEE JUNIOR	031	034	-	ST. LAWRENCE PLATFORM	FRONTENAC ARCH
LEE SENIOR	-	020	-	-	-
LEMAIRE TP	032	013	QUE.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
LENNOX FERRY	011	015	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
LIN CLS LIARD R	095	006	N.W.T.	CORDILLERAN OROGEN	
LISTER"S MILLS	021	027	N.B.	APPALACHIAN OROGEN	MARITIME FOLD BELT NE
LITTLE DAM LAKE	031	122	QUE.	GRENVILLE PROVINCE	
LITTLE NARROWS JUBILEE	011	037	N.S.	APPALACHIAN OROGEN	ALANTIC UPLANDS
LITTLE SALT COVE BROOK	001	004	NFLD.	-	AVALON PLATFORM
LITTLE TIM	082	022	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
LOCATION 124 NE WHITEFISHR	052	023	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
LOCH ERNE	-	069	-	-	WAWA BELT
LOCH LOMOND(L UIST SETT)	011	031	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
LOCH LOMOND (1 MI.NW.)	-	033	-	-	-
LOGJAM CREEK	104	021	B.C.	CORDILLERAN OROGEN	CASSIAR BELT
LOMBARD PPTY	031	062	ONT.	GRENVILLE PROVINCE	
LONG HARBOUR	001	073	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
LOON LAKE	052	071	ONT.	SOUTHERN PROVINCE	LAKE SUPERIOR BASIN
LORD AND LADY GULCH MINE	001	001	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
LORRAIN(BAROID)	105	025	Y.T.	CORDILLERAN OROGEN	SELWYN FOLD BELT
LOT 1A MACGREGOR TP	052	061	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
LOT 17 OSMUN VEIN	-	055	-	-	-
LOUISAKOFF-HILL CLS	042	008	-	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
LOWER BIRCH ISLAND	021	037	N.B.	APPALACHIAN OROGEN	MARITIME FOLD BELT
LOWER BURLINGTON(CABIN BR)	-	007	N.S.	-	-
LOWER CANOE LAKE	-	004	-	-	-
LOW GRADE CLAIMS	104	016	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
LUCKY(CAMERON)	082	036	-	-	EASTERN FOLD BELT
LUCKY JIM	104	006	-	-	INTERMONTANE BELT W
LUCKY SEVEN GRP	103	002	-	-	COAST CRYSTALLINE BELT
LUNCH POND CLAIM	001	066	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
LUX CLAIM GRP	075	003	N.W.T.	CHURCHILL PROVINCE	EAST ARM HOMOCLINENORIUM
LYALL AND BEIDELMAN PROP.	022	005	QUE.	APPALACHIAN OROGEN	GASPE SYNCLINORIUM
LYBSTER TP (R34)	052	016	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
LYNDHURST QUARTZ MINE	031	039	-	GRENVILLE PROVINCE	GRENVILLE TYPE BELT
LYNX MINE(WESTERN ML)	092	004	B.C.	CORDILLERAN OROGEN	INSULAR FOLD BELT
L. FLETCHER	011	001	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
MABOU MINES(CUVIER PPTY)	011	043	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
MACDONALD GR-KATHERINE CLM	093	013	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
MACDONALD QUARRY	031	007	ONT.	GRENVILLE PROVINCE	
MACGREGOR TP	052	059	-	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
MACKAY-EVANS MINE	011	040	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
MACKENZIE MINING (KIL)	086	006	N.W.T.	BEAR PROVINCE	COPPERMINE HOMOCLINE
MACKINNON (SCOTTSVILLE)	011	052	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
MACMILLAN SETTLEMENT	021	054	N.B.	-	CHALEUR SYNCLINORIUM
MACUMBER-DEEP HOLLOW MINES	-	008	N.S.	-	MARITIME FOLD BELT E
MADOC TP 1	031	047	ONT.	GRENVILLE PROVINCE	
MADOC TP 2	-	045	-	-	
MADOC TP 3	-	046	-	ST. LAWRENCE PLATFORM	FRONTENAC ARCH
MADOC TP 4	-	030	-	-	-
MADOC TP 5	-	022	-	-	-
MAINLAND OPPOSITE PIC IS	042	009	-	SUPERIOR PROVINCE	WAWA BELT
MALBAIE R CORBEAU.CAPE	021	050	QUE.	GRENVILLE PROVINCE	BAIE COMEAU BELT
MALLARD LAKE PROJ	032	005	ONT.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT

NAME	QUADRANGLE NUMBER	SEQUENCE NUMBER	POLITICAL PROVINCE	TECTONIC PROVINCE	TECTONIC SUBPROVINCE
MANITOUWANING	041	001	-	ST. LAWRENCE PLATFORM	ALGONQUIN ARCH B
MANNERS SUTTON	021	025	N.B.	APPALACHIAN OROGEN	FREDERICTON SYNCLINORIUM
MANUELS-TOPSAIL AREA	001	070	NFLD.	-	AVALON PLATFORM
MANVILLE GRP (BIG BULL)	104	013	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
MARKHAMVILLE MINE	021	022	N.B.	APPALACHIAN OROGEN	CAPE SPLIT BASIN
MARMORA	031	033	ONT.	GRENVILLE PROVINCE	FRONTENAC ARCH
MATTE ZONE	-	133	QUE.	-	
MAZOKAMA BAY PROS.TB4500SE	052	090	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
MCBEAN BROOK	021	036	N.B.	APPALACHIAN OROGEN	FREDERICTON SYNCLINORIUM
MCBEATH	031	041	ONT.	ST. LAWRENCE PLATFORM	FRONTENAC ARCH
MCQUISH(MOSELEY MINE)	011	034	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
MCEWEN PROSPECT	031	056	ONT.	GRENVILLE PROVINCE	
MCILROY MINE	-	015	-	-	
MCINTYRE LOT 53	052	052	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
MCISAAC POINT	011	027	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
MEADOW WOODS VEIN	001	057	NFLD.	-	AVALON PLATFORM
MELFORD	011	010	N.S.	-	MARITIME FOLD BELT
MELMERBY BEACH	-	016	-	-	-
MEL-JEAN CLAIMS	095	002	Y.T.	CORDILLERAN OROGEN	MACKENZIE FOLD BELT
MEMRAMCOOK COPPER MINE	021	033	N.B.	APPALACHIAN OROGEN	MARITIME FOLD BELT
METHUEN LEAD VEIN	031	049	ONT.	GRENVILLE PROVINCE	LAURENTIAN HIGHLANDS
MIDDLE BIGHT COVE	001	027	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
MIDDLE STEWIACKE	011	003	N.S.	-	MARITIME FOLD BELT
MIDNIGHT (CHISHOLM) CLAIM	093	005	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
MILLAR PPTY	052	079	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
MILLER	031	031	-	ST. LAWRENCE PLATFORM	FRONTENAC ARCH
MILL BROOK(FINLAY POINT)	011	051	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
MINERAL KING	082	034	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT
MINE COVE	001	036	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
MINK ISLAND	052	006	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
MNG LOC 277	-	009	-	-	-
MONA PROPERTY	093	086	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
MONMOUTH TP	031	076	ONT.	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
MONTGOMERY PPTY	-	080	-	-	-
MOORES PIT	011	050	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
MOOSE GRP MACMILLAN PASS	105	021	Y.T.	CORDILLERAN OROGEN	SELWYN FOLD BELT
MORDEN VERONA DEP	031	036	ONT.	GRENVILLE PROVINCE	GRENVILLE TYPE BELT
MOSS MINE	-	113	QUE.	-	
MOULTON HILL-ALDERMAC MINE	021	016	-	ST. LAWRENCE PLATFORM	GASPE SYNCLINORIUM
MOUNT ALCOCK	094	025	B.C.	CORDILLERAN OROGEN	ROCKY MTN THRUST BELT
MOUNTAIN BOY GROUP	104	009	-	-	INTERMONTANE BELT W
MOUNTAIN CHIEF GROUP	082	028	-	-	OMINECA CRYSTALLINE BELT
MOUNT AETNA MINE	041	006	ONT.	SOUTHERN PROVINCE	PENOKEAN FOLD BELT
MOUNT MARGARET SPAR FLOAT	001	053	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
MOUNT ROYAL	031	099	QUE.	ST. LAWRENCE PLATFORM	QUEBEC BASIN
MOUNT ST HILAIRE	-	107	-	-	-
MT PLEASANT MINE	021	018	N.B.	APPALACHIAN OROGEN	FREDERICTON SYNCLINORIUM
MUNCHO L	094	011	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT NE
MUNROE L GRANITE	064	002	MAN.	CHURCHILL PROVINCE	ENNADAI FOLD BELT
MURPHY-HICKEY PPTY	031	051	ONT.	GRENVILLE PROVINCE	
MURPHY-HICKEY	-	052	-	-	
MURPHY MINE	-	059	-	GRENVILLE PROVINCE	LAURENTIAN HIGHLANDS
MUSKATEER GROUP	103	016	B.C.	CORDILLERAN OROGEN	COAST CRYSTALLINE BELT
M MACMILLAN MINE	011	040	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
NASH CREEK SILVER	021	055	N.B.	APPALACHIAN OROGEN	CHALEUR SYNCLINE
ND	-	061	NFLD.	-	SELWYN FOLD BELT
NEEPATYRE MINE-WALBRIDGE	052	040	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
NEPEAN TP	031	092	-	ST. LAWRENCE PLATFORM	OTTAWA EMBAYMENT
NEWMAN DEPOSIT	-	134	-	GRENVILLE PROVINCE	
NEW BLACK DUCK VEIN	001	044	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
NICHOLAS-RIOUX SEIGNURY	022	003	QUE.	-	QUEBEC ANTICLINORIUM
NIFTY 1-5 AND THUNDER CLS	093	003	B.C.	CORDILLERAN OROGEN	COAST CRYSTALLINE BELT
NINE MILE BROOK	021	045	N.B.	APPALACHIAN OROGEN	MIRAMACHI ANTICLINORIUM
NIPIGON TP	052	000	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
NONDA CR	094	012	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT NE
NORMA LUCKY LU CLS	105	011	Y.T.	-	OMINECA CRYSTALLINE BELT
NORTHSTAR CLAIM	103	014	B.C.	-	COAST CRYSTALLINE BELT
NORTH AMERICAN SILVER	041	013	ONT.	SOUTHERN PROVINCE	COBALT EMBAYMENT
NORTH GRENVILLE	011	010	N.S.	APPALACHIAN OROGEN	CAPE SPLIT BASIN
NORTH REYNOLDS	031	025	ONT.	GRENVILLE PROVINCEORM	
NORTH STAR MINE	-	129	QUE.	GRENVILLE PROVINCE	
NOYES MINE	-	012	ONT.	ST. LAWRENCE PLATFORM	FRONTENAC ARCH
NO. ONE	082	014	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
NUETLIN L N ENNADAI L S	064	003	MAN.	CHURCHILL PROVINCE	ENNADAI FOLD BELT
N BURGESS	031	065	ONT.	GRENVILLE PROVINCE	
N MACMILLAN R	105	023	Y.T.	CORDILLERAN OROGEN	SELWYN FOLD BELT
N TROUT RIVER AREA	011	042	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
ODERIN ISL	001	067	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
OGEMA MINE	052	000	ONT.	SOUTHERN PROVINCE	LAKE SUPERIOR BASIN
ONIKODASIK.R MOUTH	032	011	QUE.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
OLD LEDUC MINE	031	126	-	GRENVILLE PROVINCE	ONTARIO GNEISS BELT NE
OLD SILVER LEAF PGMT	052	097	MAN.	SUPERIOR PROVINCE	WABIGOON BELT
OMINECA QUEEN	093	014	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
ONSLOW R3 L13	031	104	QUE.	GRENVILLE PROVINCEORM	
ONSLOW R4 L13	-	105	-	-	
ONSLOW TP 1	-	103	-	ST. LAWRENCE PLATFORM	
ONSLOW TP 2	-	101	-	-	
ORO SHOWING	105	016	Y.T.	CORDILLERAN OROGEN	MACKENZIE FOLD BELT
OTTAWA MINE	082	020	B.C.	-	OMINECA CRYSTALLINE BELT
OTTERRUB VEIN	001	054	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
OZONE SIDING LEWIS SEYLER	052	092	ONT.	SOUTHERN PROVINCE	
OZONE ?IDING MCL TB4500	-	093	-	SOUTHERN PROVINCEE	

NAME	QUADRANGLE NUMBER	SEQUENCE NUMBER	POLITICAL PROVINCE	TECTONIC PROVINCE	TECTONIC SUBPROVINCE
PAIPOONGE TP	052	041	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
PALETTE IS	-	065	-	-	-
PALMATEER	031	003	-	ST. LAWRENCE PLATFORM	
PARASSEUX RAPIDS VEIN	052	043	-	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
PARSONS MINE LILY OF VALLY	-	038	-	-	-
PARSON(HILLTOP SNOWDROP)	082	044	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT
PARTRIDGE CROP LAKE AREA	063	002	MAN.	CHURCHILL PROVINCE	
PARTRIDGE CR	105	002	Y.T.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
PEERLESS MINE (R150)	052	024	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
PEGGY(FORMERLY MARY)	075	006	N.W.T.	CHURCHILL PROVINCE	EAST ARM FOLD BELT
PEGLEG(NEEPAWA GRP)	082	024	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
PEKANATUI POINT	075	001	N.W.T.	CHURCHILL PROVINCE	EAST ARM HOMOCLINE
PEMBROKE(GLENBERVIE)	011	006	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
PERCH COVE	001	040	NFLD.	-	AVALON PLATFORM
PERRY LAKE	031	016	ONT.	GRENVILLE PROVINCE	FRONTENAC ARCH
PERRY MINE	-	017	-	-	GRENVILLE TYPE BELT
PETE	105	042	Y.T.	CORDILLERAN OROGEN	ROCKY MTN THRUST BELT
PETER CAMPBELL MINE	011	053	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
PHILLIPS CR	082	003	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT
PIE	094	029	-	-	ROCKY MTN THRUST BELT
PIKE LAKE VEINS	052	073	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
PINCHI LAKE MINE MERCURY C	093	012	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
PINK MINE	031	097	ONT.	GRENVILLE PROVINCE	
PIONEER MINE	092	011	B.C.	CORDILLERAN OROGEN	COAST CRYSTALLINE BELT
PIPESTONE ISLAND	062	001	MAN.	SUPERIOR PROVINCE	ENGLISH R GNEISS BELT
PLAIN	031	043	ONT.	ST. LAWRENCE PLATFORM	FRONTENAC ARCH
PLEASANT BAY	011	060	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
POLARIS MINE	068	001	MAN.	ARCTIC PLATFORM	CORNWALLIS FOLD BELT
PONTEFRACT A-2 3	031	132	QUE.	GRENVILLE PROVINCE	
PONTON	-	032	ONT.	ST. LAWRENCE PLATFORM	FRONTENAC ARCH
PORCUPINE CREEK	082	049	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT E
PORPHYRY ISLAND	052	046	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
PORT-ARTHUR SILVER 1	-	054	-	-	-
PORT DANIEL	021	056	QUE.	APPALACHIAN OROGEN	CHALEUR SYNCLINORIUM
PREMIER LANGMUIR MINE	042	006	ONT.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
PRICE PPTY(WESTERN ML)	092	003	B.C.	CORDILLERAN OROGEN	INSULAR BELT
PRINCE"S MINE	052	005	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
QUARTZ LAKE	095	001	Y.T.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
QUEBEC CITY	021	044	QUE.	ST. LAWRENCE PLATFORM	QUEBEC BASIN
QUEBEC STURGEON RIVER M L	032	014	-	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
QUEENS BROOK FLUORITE	021	021	N.B.	APPALACHIAN OROGEN	FREDERICTON SYNCLINORIUP
QUICK WOOD VEIN	001	030	NFLD.	-	AVALON PLATFORM
QUYON	031	102	QUE.	GRENVILLE PROVINCE	
RABBIT MTN JR MINE ML 57	052	028	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
RABBIT MTN MINE	052	027	-	-	-
RAGGED HEAD	001	026	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
RAINVILLE(DUGAS) MINE	031	115	QUE.	GRENVILLE PROVINCE	
RAIN-SNOW CLAIMS	106	001	N.W.T.	CORDILLERAN OROGEN	MACKENZIE FOLD BELT NE
RAIN(1-10)	094	006	B.C.	-	
RAMSEY MINE	031	006	ONT.	GRENVILLE PROVINCE	LAURENTIAN HIGHLANDS
RANTEM COVE	001	008	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
REAR BLACK RIVER	011	021	N.S.	-	MARITIME FOLD BELT
RED HEAD VEIN	001	002	NFLD.	-	AVALON PLATFORM
RED ROBIN-MORRIS LEASES	-	032	-	-	-
RED TOP GROUP	104	003	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
REMO CLS	082	039	-	-	OMINECA CPYSTALLINE BELT
REXSPAR(BIRCH ISLAND)	-	051	-	-	INTERMONTANE BELT W
REX GROUP (ABCDE STEVENS)	075	004	N.W.T.	CHURCHILL PROVINCE	EAST ARM FOLD BELT
RICHARDSON	031	070	ONT.	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
RIVER JORDAN DEPOSIT	082	048	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
ROBINSON GROUP	031	054	ONT.	GRENVILLE PROVINCE	
ROCKSLIDE CR 1	115	002	Y.T.	CORDILLERAN OROGEN	ST ELIAS FOLD BELT
ROCKSLIDE CR 2	-	003	-	-	YUKON CRYSTALLINE PLATFRM
ROCKY BROOK	021	041	N.B.	APPALACHIAN OROGEN	FREDERICTON SYNCLINORIUP
ROCKY POND	001	059	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
ROCK CANDY FLUORITE MINE	082	009	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
ROGERS	031	021	ONT.	GRENVILLE PROVINCE	GRENVILLE TYPE BELT
ROGER"S HILL	011	019	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
ROK CAT	082	008	B.C.	CORCILLERAN OROGEN	ROCKY MTN THRUST BELT
ROMAINES BROOK	012	004	NFLD.	APPALACHIAN OROGEN	WESTERN PLATFORM
RONAN DEPOSIT	-	005	-	-	AVALON PLATFORM
ROOKS	031	042	ONT.	ST. LAWRENCE PLATFORM	FRONTENAC ARCH
ROSS 1	-	124	-	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
ROSS 2	-	125	-	-	-
ROTI POINT	001	089	NFLD.	APPALACHIAN OROGEN	HERMITAGE FLEXURE
RUBY CLAIM(SHUNIAH MINE)	104	008	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT W
RUBY GRP TORIC MINE	103	015	-	-	COAST CRYSTALLINE BELT
RUSH AND STANNITE GROUPS	052	100	MAN.	SUPERIOR PROVINCE	WABIGOON BELT
RYANS BROOK	011	062	NFLD.	APPALACHIAN OROGEN	WESTERN PLATFORM
RYAN"S HILL VEIN	001	050	-	-	AVALON PLATFORM
R ROCK 89 TALTHEILEI NAR	085	004	N.W.T.	CHURCHILL PROVINCE	EAST ARM HOMOCLINE
R 110 SILVER FALLS	052	014	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
R 111 LYBSTER TP	-	018	-	-	-
R 115 TCHIATIN"S VEIN	-	019	-	-	-
R 135 WOODSIDE"S VEIN	-	022	-	-	-
R 78 LYBSTER TP	-	017	-	-	-

NAME	QUADRANGLE NUMBER	SEQUENCE NUMBER	POLITICAL PROVINCE	TECTONIC PROVINCE	TECTONIC SUBPROVINCE
SALMON HOLE	001	051	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
SALT COVE VEIN	001	007	"	"	"
SANTACK	052	077	ONT.	SOUTHERN PROVINCE	LAKE SUPERIOR BASIN NE
SAWPIT COVE	021	003	N.B.	APPALACHIAN OROGEN	MARITIME FOLD BELT
SCATTER RIVER	094	023	B.C.	CORDILLERAN OROGEN	ROCKY MTN THRUST BELT
SCHICKLER FARM	031	001	ONT.	GRENVILLE PROVINCE	ONTARIO GNEISS BELT NE
SCOTSVILLE DEPOSIT	011	054	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
SCOT CLAIMS	105	027	Y.T.	CORDILLERAN OROGEN	SELWYN FOLD BELT
SCRAPE VEIN	001	040	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
SCRIPTURE"S VEIN	052	012	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
SEAGULL CREEK	105	003	Y.T.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
SEATON ISLAND	052	095	ONT.	SUPERIOR PROVINCE	WABIGOON VOLCANIC BELT
SENECA(ZENITH) DEP	092	002	B.C.	CORDILLERAN OROGEN	INTERMONTANE BELT
SERRATED HILLS	001	003	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
SF PROPERTY	104	011	B.C.	CORDILLERAN OROGEN	KLASTLINE PLATEAU W
SHARP PEAK	001	061	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
SHATFORD L(E-END)	052	098	MAN.	SUPERIOR PROVINCE	
SHATTER CLIFF	001	058	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
SHAW-CHURCHILL MINE	021	014	N.S.	"	MARITIME FOLD BELT
SHEARSTICK BROOK	001	063	NFLD.	"	AVALON PLATFORM
SHELLY CAROLE	082	032	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT NE
SHENACADIE	011	038	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
SHENANGO-RAINBOW CLS	082	001	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
SHIPS COVE	012	001	NFLD.	APPALACHIAN OROGEN	WESTERN PLATFORM
SHOAL COVE POND	001	010	"	"	AVALON PLATFORM
SHUNIAH MINE-DUNCAN MINE	052	057	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
SICOTTE TP	031	141	QUE.	GRENVILLE PROVINCE	QUEBEC GNEISS BELT
SILVER BASIN CLAIM	105	032	Y.T.	CORDILLERAN OROGEN	EASTERN FOLD BE
SILVER CLIFF MINE	001	068	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
SILVER DIAMOND	104	020	B.C.	CORDILLERAN OROGEN	
SILVER GIANT MINE	082	043	"	"	EASTERN FOLD BELT W
SILVER HOARD CLAIM	"	016	"	"	OMINECA BELT
SILVER ISLAND PROPERTY	093	008	"	"	INTERMONTANE BELT W
SILVER ISLET MINE	052	033	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
SILVER L VEINS	"	060	"	"	LAKE SUPERIOR BASIN NE
SILVER MTN MINES	"	013	"	"	PORT ARTHUR HOMOCLINE
SILVER SPRAY GRP	082	033	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT
SILVER TIP	104	004	"	"	COAST CRYSTALLINE BELT
SISTERS BROOK	021	040	N.B.	APPALACHIAN OROGEN	FREDERICTON SYNCLINORIUM
SMITHFIELD PB-ZN MINE	011	004	N.S.	"	MARITIME FOLD BELT
SNOWDRIFT-MARY CLS	075	002	N.W.T.	CHURCHILL PROVINCE	EAST ARM HOMOCLINE
SNOW	094	014	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT
SNUFF CHANNEL (E.OF)	085	001	N.W.T.	CHURCHILL PROVINCE	EAST ARM FOLD BELT W
SOUTHERN CROSS VEINS	001	037	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
SOUTHWEST MIRAMICHI RIVER	021	039	N.B.	"	FUNDY SUCCESSOR BASIN
SOUTHWEST MIRAMICHI RIVER	"	030	"	"	"
SOUTH MCKELLAR ISLAND	052	009	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
SOUTH NEWBRIDGE	021	035	N.B.	APPALACHIAN OROGEN	FREDERICTON SYNCLINORIUM
SOUTH REYNOLDS	031	014	ONT.	GRENVILLE PROVINCE	FRONTENAC ARCH
SPAR ISLAND-PRINCE PPTY	052	004	"	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
SPECTROAIRS NA CLAIMS	086	005	N.W.T.	BEAR PROVINCE	COPPERMINE HOMOCLINE
SPECULATOR GRP	082	021	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
SPICERS COVE	021	017	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
SPICES COVE(LANN HEAD)	001	005	NFLD.	"	AVALON PLATFORM
STAG BAY	013	002	"	CHURCHILL PROVINCE	MAKKOVIK FOLD BELT
STAR MINE	052	028	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
STETSON-CUTLER QUARRY	021	015	N.B.	APPALACHIAN OROGEN	FREDERICTON SYNCLINORIUM
STEWART MINE	031	026	ONT.	ST. LAWRENCE PLATFORM	
STEWART QUARRY MAY ST	052	053	"	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
STIRLING(MINDAMAR) MINE	011	024	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
STROUDS HILL (OLD BALDY)	001	075	NFLD.	"	AVALON PLATFORM
STURGIS-FEUCHTWANGER MINES	021	011	N.S.	"	MARITIME FOLD BELT
ST CLAIR PPTY	052	002	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
ST FABIEN TP	022	002	QUE.	APPALACHIAN OROGEN	QUEBEC ANTICLINORIUM
ST HELEN ISLAND	031	100	"	ST. LAWRENCE PLATFORM	QUEBEC BASIN
ST HONORE	022	004	"	GRENVILLE PROVINCE	
ST LAWRENCE COLUMBIUM MINE	031	098	"	ST. LAWRENCE PLATFORM	QUEBEC BASIN
ST MARY"S POINT	021	028	N.B.	APPALACHIAN OROGEN	MARITIME FOLD BELT E
ST MARY'S	040	002	ONT.	ST. LAWRENCE PLATFORM	ALGONQUIN ARCH
ST MICHEL SILL	031	119	QUE.	"	QUEBEC BASIN
ST PASCAL	021	052	"	APPALACHIAN OROGEN	QUEBEC ANTICLINORIUM
ST UBALD PARISH	031	142	"	ST. LAWRENCE PLATFORM	QUEBEC BASIN
SULPHUR CREEK	094	013	B.C.	CORDILLERAN OROGEN	ROCKY MTN THRUST BELT
SUNDAY CLAIM	082	050	"	"	EASTERN FOLD BELT E
SUTTON SHOWING	001	086	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
SWIM LAKE PPTY	105	013	Y.T.	CORDILLERAN OROGEN	SELWYN FOLD BELT
S MACMILLAN R	"	010	"	"	OMINECA CRYSTALLINE BELT

NAME	QUADRANGLE NUMBER	SEQUENCE NUMBER	POLITICAL PROVINCE	TECTONIC PROVINCE	TECTONIC SUBPROVINCE
TAN(LIARD CROSSING)	094	020	B.C.	CORDILLERAN OROGEN	MACKENZIE FOLD BELT
TANG	-	041		-	ROCKY MTN THRUST BELT
TAREFARE MINE	001	021	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
TAREFARE SHORE	-	008	-	-	-
T06030 CLAIM	052	009	ONT.	SOUTHERN PROVINCE	LAKE SUPERIOR BASIN
TEA CLAIMS	105	019	Y.T.	CORDILLERAN OROGEN	SELWYN FOLD BELT
TEE(LIARD CROSSING)	094	021	B.C.	-	MACKENZIE FOLD BELT
TERMINUS MINES	104	007	-	-	INTERMONTANE BELT W
TERRACE BAY	042	011	ONT.	SOUTHERN PROVINCE	LAKE SUPERIOR BASIN
THOMPSON ISLAND	052	007	-	-	PORT ARTHUR HOMOCLINE
THREE A MINE	-	063	-	-	-
THUBUN RIVER	085	003	N.W.T.	CHURCHILL PROVINCE	EAST ARM FOLD BELT BELT
THUNDERBAY MINE (58)	052	058	ONT.	SOUTHERN PRCVINCE	PORT ARTHUR HOMOCLINE
THUNDER BAY PB-ZN PPTY	-	007	-	-	-
TICKLE BAY (E. SIDE)	001	082	NFLD.	APPALACHIAN OROGEN	AVALCN PLATFORM
TICKLE HARBOUR PT.	-	084	-	-	-
TILT HILL	-	060	-	-	-
TIN ISLAND	052	099	MAN.	SUPERIOR PROVINCE	WABIGOON BELT
TOCHATWI BAY	075	005	N.W.T.	CHURCHILL PROVINCE	EAST ARM HOMOCLINE
TOM GRP (MBE A N D D)	105	024	Y.T.	CORDILLERAN OROGEN	SELWYN FOLD BELT
TP 87	042	012	ONT.	SUPERIOR PROVINCEE	
TRENKS PPTY	052	056	-	SOUTHERN PRCVINCE	PORT ARTHUR HOMOCLINE
TRIPP FARM	031	079	-	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
TRI GROUP (1 TO 4)	086	007	N.W.T.	BEAR PROVINCE	COPPERMINE HOMOCLINE
TRI	094	007	B.C.	CORDILLERAN OROGEN	
TROUT BR	011	057	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT NE
TUCHIALIC BAY	013	001	NFLD.	CHURCHILL PROVINCE	MAKKOVIK FOLD BELT
TULSEQUAH CHIEF-BIG BULL	104	014	B.C.	CORCILLERAN OROGEN	COAST CRYSTALLINE BELT
TWIN J MINE	092	001	-	-	INSULAR FOLD BELT
TWIN MOUNTAIN(MAX HOPE)	082	046	-	-	OMINECA CRYSTALLINE BELT
T 143 PITCH CR	052	037	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
UNION CR LEAD MINE	031	061	ONT.	GRENVILLE PROVINCE	
UPR NANSEN CR	115	004	Y.T.	CORDILLERAN OROGEN	COAST CRYSTALINE BELT
URN	105	030	-	-	
VALE CLAIM GRP	104	015	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
VALLEY VEIN	001	035	NFLD.	APPALACHIAN OROGEN	AVALON PLATFORM
VANGORDA CR PPTY	105	014	Y.T.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
VERNON, DONNA	093	015	B.C.	-	-
VICTORIA ISLAND	052	002	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
VICTORIA MINE	-	042	-	-	-
VILLENEUVE MICA MINE	031	131	QUE.	GRENVILLE PROVINCE	
WAHL PROSPECT	052	096	ONT.	SUPERIOR PROVINCE	WABIGCON VOLCANIC BELT
WALLBRIDGE PPTY	-	019	-	ST. LAWRENCE PLATFORM	OTTAWA EMBAYMENT
WALLINGFORD MINE	-	116	QUE.	GRENVILLE PROVINCE	
WALTON (MAGNET COVE)	021	013	N.S.	APPALACHIAN OROGEN	MARITIME FOLD BELT
WARATAH CLAIM	103	004	B.C.	CORDILLERAN OROGEN	INSULAR BELT BEL
WEBER GROUP	094	002	-	-	INTERMONTANE BELT E
WELCOME L	042	007	ONT.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
WELSFORD	011	023	N.S.	APPALACHIAN OROGEN	CAPE SPLIT BASIN
WEST BEAVER MINE	052	032	ONT.	SOUTHERN PROVINCE	PORT ARTHUR HOMOCLINE
WEST SHININGTREE AREA	041	010	-	SUPERIOR PROVINCE	
WEWA(RAM)	082	010	B.C.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT
WHEATON R S-FORK	105	001	Y.T.	-	COAST CRYSTALLINE BEM
WHITEMAN CR GPEEN GABLES	082	029	B.C.	-	INTERPONTANE BELT E
WIGHAM GROUP	-	041	-	-	OMINECA CRYSTALLINE BELT
WILBERMERE LAKE	031	143	ONT.	GRENVILLE PROVINCE	
WILDER(CALABOGIE)	-	089	-	-	GRENVILLE GRP BELT
WILLIAMS PPTY	-	005	-	ST. LAWRENCE PLATFORM	
WILLIAM REYNOLDS	-	038	-	-	
WINDERMERE (4 MI.SE.OF)	082	030	B.C.	CORDILLERAN OROGEN	ROCKY MTN THRUST BELT
WISE CLAIMS	105	020	N.W.T.	-	MACKENZIE FOLD BELT NE
WOLFE L AREA	-	009	Y.T.	-	OMINECA CRYSTALLINE BELT
WOLF(BEAR)	094	022	B.C.	-	EASTERN FOLD BELT
WOLF CLAIM(LOC 184)	103	006	-	-	COAST CRYSTALLINE BELT
WOODCOX FELDSPAR MINE	031	008	ONT.	GRENVILLE PROVINCE	ONTARIO GNEISS BELT
WOODRUFFE MINE	-	002	-	ST LAWRENCE LOWLANDS	
WOOD ISLAND	021	002	N.B.	APPALACHIAN OROGEN	MARITIME FOLD BELT
WRIGHT HARGREAVES MINE	042	005	ONT.	SUPERIOR PROVINCE	ABITIBI VOLCANIC BELT
WRIGHT	031	008	-	ST. LAWRENCE PLATFORM	FRONTENAC ARCH
YARROW BARITE MINE	041	015	ONT.	SOUTHERN PROVINCE	COBALT EMBAYMENT
YORK HILLS	021	024	N.B.	APPALACHIAN OROGEN	FREDERICTON SYNCLINORIUM
YORNOC DAVE	082	031	B.C.	CORDILLERAN OROGEN	EASTERN FOLD BELT
ZINC GROUP(NN)	105	010	Y.T.	CORDILLERAN OROGEN	OMINECA CRYSTALLINE BELT

Table 34. Major elements and development code of Canadian barium, strontium and fluorine deposits

ELEMENTS 1	2	3	4	DEVELOPMENT CODE 1979 (see introduction, text)	NAME	NTS NO	SEQUENCE NO
AG	FE	CO	NI	DEVELOPED PROSPECT	NORTH AMERICAN SILVER	041	013
	BA	F	ZN	-	KELLOW PPTY(ML42)	052	050
	F	FE	PB	-	AUGUSTA MINE	052	011
	CU	ZN	F	-	ELGIN VEIN	052	036
	CO	ZN	PB	OCCURRENCE	KATHERINE LEAD MINES	031	058
	PB	F		-	PORCUPINE CREEK	082	049
	ZN	PB	BA	-	TOM GRP (MBE A N D D)	105	024
	BA			-	NORTHSTAR CLAIM	103	014
	PB	BA		-	CHRYSLER LEAD PPTY	031	068
	PB	BA		-	NASH CREEK SILVER	021	055
	BA			-	VICTORIA ISLAND	052	002
	CU	BA		-	ANNA GRP	082	019
	BA			-	MOUNTAIN BOY GROUP	104	009
	PB	BA		-	EVENING SUN CLAIM	103	019
	PB	BA		-	RUBY GRP TORIC MINE	103	015
	PB	ZN	F	-	CRESWEL(BADGER MINE)	052	026
	PB	ZN	BA	-	BUCK GROUP	093	007
	PB	ZN	CU	-	TWIN MOUNTAIN(MAX HOPE)	082	046
	PB	ZN	BA	-	BEVERLY GROUP	094	004
	PB	ZN	F	-	MOUNTAIN CHIEF GROUP	082	028
	BA	PB	ZN	-	SILVER ISLAND PROPERTY	093	008
	BA	F		-	R 70 LYBSTER TP	052	017
	BA			-	THOMPSON ISLAND	052	007
	F	ZN		-	WEST BEAVER MINE	052	032
	CU	F		-	BONANZA GRP-COWDELL POINT	086	002
	ZN	BA		-	BEAVER JR	052	034
	PB	ZN		-	BELLEKENO MINE	105	031
	F	ZN	PB	-	RABBIT MTN JR MINE ML 57	052	028
	PB	ZN	F	-	VICTORIA MINE	052	042
	PB	ZN	BA	PAST PRODUCER	HOMESTAKE GRP	082	045
	PB	ZN	F	-	PEGLEG(NEEPAWA GRP)	082	024
	PB	ZN	BA	-	JARVIS ISLAND	052	003
	PB	BA		-	SPECULATOR GRP	082	021
	PB	ZN	BA	-	DOLLY VARDEN MINE-WOLF GRP	103	013
	CO	ZN	PB	-	SILVER ISLET MINE	052	033
	PB	ZN	BA	-	CRESWEL(PORCUPINE MINE)	052	025
	ZN	PB	F	-	CLIMAX KEYSTONE MINE	052	030
	ZN	PB	BA	-	TERMINUS MINES	104	007
	PB	BA		-	CASINO CREEK	115	006
	PB	ZN	AU	-	OTTAWA MINE	092	020
	PB	ZN	F	-	KOOTENAY FLORENCE	082	012
	PB	ZN	BA	-	HIGHLAND LIGHT	082	026
	ZN	PB	PY	-	BEAVER MINE(ML T97)	052	031
	BA	ZN	PB	-	SPAR ISLAND-PRINCE PPTY	052	004
	PB	ZN	BA	-	ALMA(MYRTLE) GRP	082	023
	PB	AU	BA	-	WOLF CLAIM(LOC 184)	103	006
	PB	ZN	BA	-	THREE A MINE	052	063
	PB	ZN	F	-	NO. ONE	082	014
	PB	ZN	BA	-	LITTLE TIM	082	022
AG	PB	ZN	CO	PAST PRODUCER	BECK MINE	052	060
	ZN	PB	F	-	RABBIT MTN MINE	052	027
	PB	F		-	CRESWEL(SILVER CR MINE)	052	029
	PB	ZN	F	-	SILVER MTN MINES	052	013
	ZN	PB	F	-	SHUNIAH MINE-DUNCAN MINE	052	057
AS	AG	BA	PB	PAST PRODUCER	EDWARD ISLAND	052	044
AU	F	PB	FE	OCCURRENCE	BLOCK B CLS	032	006
	AG	CU	BA	-	LUCKY SEVEN GRP	103	002
	AG	F	MO	-	ARSENO GRP	085	005
	BA	SR		-	HORSEFLY PLACER	093	001
	AG	PB	BA	-	LAST CHANCE GRP.	103	005
	BA	W	SN	-	ARIZONA CR	115	007
	F	CU	PB	-	DINGO GROUP	086	001
	PB	BA	ZN	-	UPR NANSEN CR	115	004
	F			-	LOUISAKOFF-HILL CLS	042	008
	BA	SN		PAST PRODUCER	GRAND FORKS	115	008
	BA			-	WRIGHT HARGREAVES MINE	042	005
	F			-	CANADIAN MALARTIC GML	032	002
	BA			-	PIONEER MINE	092	011

ELEMENTS 1	2	3	4	DEVELOPMENT CODE 1979	NAME	NTS NO	SEQUENCE NO
BA	PB	ZN		-	BELLMANS COVE	012	008
				-	HALLOWELL GRANT- FAIRMOUNT	011	022
				-	BAR PROSPECT	105	026
	FE			-	MELMERBY BEACH	011	016
				-	BELLEVUE (BELLEVUE PEN.W.)	001	081
				-	L. FLETCHER	011	001
				-	DESOLATION CREEK S	082	002
				-	SULPHUR CREEK	094	013
				-	CAPE MILLE	001	077
	F			-	JUDIQUE (CHAPEL BROOK)	011	036
	PB	ZN		-	ANDERSON-BINGHAM PPTY	052	083
				-	GALLAS POINT	011	045
				-	RANTEM COVE	001	088
				-	MELFORD	011	010
	F	AG		-	BLACK R FALLS	042	010
				-	CRIBBONS (CREBBING) POINT	011	029
				-	CUSLETT COVE S SIDE	001	052
				-	LAKEVALE	011	032
				-	OMINECA QUEEN	093	014
				-	ARISAIG AGLT QUARRY	011	030
	F			-	ENGLISH HARBOUR EAST W.SID	001	078
				-	LENNOX FERRY	011	015
				-	A J MACLEAN VEIN	011	044
	CU	F		-	JOHN CRAWFORD II	031	066
				-	TICKLE BAY (E. SIDE)	001	082
				-	SPICERS COVE	021	017
	PB	ZN		-	HYMER"S VEIN	052	021
	ZN	BA	CU	-	MABOU MINES(CUVIER PPTY)	011	043
	AG	PB	ZN	-	SILVER SPRAY GRP	082	033
				-	BLACK (BROCK) RIVER	021	023
				-	PIPESTONE ISLAND	062	001
	F			-	N TROUT RIVER AREA	011	042
				-	ONSLOW R3 L13	031	104
				-	SUTTON SHOWING	001	086
				-	EL PASO GRP	092	009
	PB			-	JOHN MURPHY	031	048
				-	MIDDLE BIGHT COVE	001	027
				-	KLUANE L	115	001
	PB	ZN		-	CROWN KING LEAD PROSPECT	031	060
	PB			-	BUTTERILL	031	053
	PB			-	PIKE LAKE VEINS	052	073
				-	MILL BROOK(FINLAY POINT)	011	091
				-	CYPRESS LAKE	072	001
				-	BIG MARSH	011	026
BA	W	AU		OCCURRENCE	ANNIE LAURIE CL	103	001
				-	SERRATED HILLS	001	083
				-	BRIAND	021	051
	MN	CA		-	SHAW-CHURCHILL MINE	021	014
	PB	CU		-	BUCK ISLAND	052	062
	F			-	ALASKA HWY MI 472	094	015
	GY	CU		-	SHIPS COVE	012	001
				-	FENSTER CR S	082	006
	PB	ZN	CU	-	NIPIGON TP	052	088
	PB			-	JUNE, SILVER TIP, ALL BLUE	082	025
				-	HIDDEN TREASURE MINE	052	010
				-	WINDERMERE (4 MI.SE.OF)	082	030
	CU			-	PORPHYRY ISLAND	052	046
	PB	CU		-	LUCKY JIM	104	006
				-	AMEDEE COMUS	011	058
	PB	ZN		-	VALE CLAIM GRP	104	015
	PB			-	NORMA LUCKY LU CLS	105	011
				-	DOE HILLS	001	076
				-	GLITTER POND	012	003
	PB			-	CLIFTON-STONEHAVEN	021	053
	PB	ZN		-	MILLAR PPTY	052	079
	ZN			-	HIGHLAND GRP.	103	008
				-	CLYDE SMITH CLS	105	020
	SP			-	BYERS CREEK	011	014
				-	JOHN CAMERON	041	014
	PB	ZN		-	GOODMORNING LAKE	052	081
				-	SNOWDRIFT-MARY CLS	075	002
	CU			-	PEKANATUI POINT	075	001
				-	BAYFIELD	021	034
	F			-	SCHICKLER FARM	031	081

BA				DEVELOPED PROSPECT	ORO SHOWING	105	016
	ZN	PB		-	MEL-JEAN CLAIMS	095	002
				-	BASS RIVER	011	011
	PB	ZN		-	ROBINSON GROUP	031	054
				-	PEGGY(FORMERLY MARY)	075	006
	PB	S		-	KEN CLAIMS	106	003
	PB	AG	ZN	-	ATAN-AUGUST CL GRPS	104	017
				-	LOWER BURLINGTON(CABIN BR)	021	007
	PB	ZN		-	GORMAN PPTY-ANGERS STA	031	114
				-	EXTENDER MINERALS	041	007
	F			-	COE PPTY	031	018
	PB			-	HOLLANDIA LEAD MINE	031	057
				-	MOOSE GRP MACMILLAN PASS	105	021
	SR			-	DORCHESTER(DORBECK)	021	031
				-	LAWSON TP	041	009
	F			-	GEM(LIARD CROSSING)	094	016
	CU	SB	SB	-	CLYDE FORKS	031	085
	F			-	MADOC TP 1	031	047
	F	CU	PB	-	MEMRAMCOOK COPPER MINE	021	033
	CL	PB	CU	-	NEEPATYRE MINE-WALBRIDGE	052	048
	F			-	MADOC TP 2	031	045
				OCCURRENCE	SCATTER RIVER	094	023
	PB	AG		-	CASHEL TP	031	070
				-	WELSFORD	011	023
BA				OCCURRENCE	MACMILLAN SETTLEMENT	021	054
				-	BRIDGEVILLE	011	009
	PB	CU		-	BEACH BARYTE PROSPECT	021	048
				-	MCEWEN PROSPECT	031	056
				-	LAST MTN	095	003
				-	DEVIL"S KITCHEN	001	064
	PB			-	NICHOLAS-RIOUX SEIGNURY	022	003
				-	LAST MOUNTAIN (4.4MI.NW)	095	005
	CU	AG		-	R ROCK B9 TALTHEILEI NAR	085	004
				-	GREAT VILLAGE	011	007
	ZN	AG	BA	-	NIFTY 1-5 AND THUNDER CLS	093	003
				-	HULL TP	031	109
				-	OTTERRUB VEIN	001	054
				-	TEA CLAIMS	105	019
	MN	CA		-	FEUCHTWANGER PPTY	021	012
				-	BRIERLY BROOK	011	017
	F		PB	-	T 143 PITCH CR	052	037
				-	MCISAAC POINT	011	027
	PB	ZN	CU	-	KARIES CLAIP	052	076
				-	SCOT CLAIMS	105	027
				-	COG LAKE	031	006
				-	WISE CLAIMS	105	028
	CU			-	ODERIN ISL	001	067
	CU			-	MACKENZIE MINING (KIL)	086	006
				-	WELCOME L	042	007
				-	BELLEVUE	001	080
	PB	ZN		-	ST FABIEN TP	022	002
	PB	ZN		-	BOURRET SHOWING	031	117
	AU			-	WEST SHININGTREE AREA	041	010
	PB			-	LOMBARD PPTY	031	062
	F			-	ONSLOW TP 1	031	103
				-	LAST MOUNTAIN (2.8 MI.NW)	095	004
				-	FENSTER CR N	082	007
	MN			-	BRIDGEVILLE(E R PICTOU)	011	013
	PB			-	ST PASCAL	021	052
				-	N MACMILLAN R	105	023
				-	S MACMILLAN R	105	018
	PB	ZN		-	JOHN PPTY	052	047
	F			-	ONSLOW R4 L13	031	105
	CU			-	LUX CLAIM GRP	075	003
				-	ST MARY"S POINT	021	028
				-	ROGER"S HILL	011	019
	F			-	ONSLOW TP 2	031	101
				-	SHENACADIE	011	038
				-	BIG TROUT BAY	052	001
				-	ART EKWI N	105	033
	CU			-	RAGGED HEAC	001	026
				-	LOCH LOMOND (1 MI.NW.)	011	033
				-	JOHNSTON SHOWING	052	072
	PB	CU	AG	OCCURRENCE	CARLICK GRP - ATAN LAKE	104	018
				-	TICKLE HARBOUR PT.	001	084
				-	NORTH GRENVILLE	011	018
	U	TH		-	EDGAR LAKE AREA	024	001
				-	RAIN-SNOW CLAIMS	106	001

	PB			-	SOUTH NEWBRIDGE	021	035
	PB	CU	AG	-	SHELLY CAROLE	082	032
				-	BA CLAIMS	105	029
	PB			-	GRAND MANAN IS	021	001
				-	HOWES PROSPECT	031	044
	PB	ZN		-	LUCKY(CAMERON)	092	036
				-	DEVILS WAREHOUSE IS	041	008
	CU	PB		-	EVERGREEN CLAIMS	093	011
	AG	PB		-	CALUMET-HECLA GRP	082	018
	AG	PB	ZN	-	DAVID COPPERFIELD GRP.	103	012
				-	NONDA CR	094	012
	SB	PB	AG	-	FLEMING-PORTER CLS	105	006
	F	AG		-	PARSONS MINE LILY OF VALLY	052	038
				-	PERCH COVE	001	048
	F			-	MUNCHO L	094	011
	F	CU		-	EUSEBE POIRIER	011	056
				-	CROSS POINT	001	047
	PB	ZN		-	GUNTER	031	071
	CU	AU		-	MOUNT AETNA MINE	041	006
BA	CU	PB	ZN	OCCURRENCE	BIEDERMAN CLAIM	042	001
	ZN	PB		-	LOON LAKE	052	071
				-	PORT DANIEL	021	056
	AG	PB	ZN	-	CUMBERLAND GR. MOUNT MADGE	104	018
				-	BOTTING OCCURRENCE	031	028
	CU	F	MN	-	MACKINNON (SCOTTSVILLE)	011	052
	AU	SB		-	EMMONS HILL PPTY	115	005
	F			-	PALETTE IS	052	065
	F			-	EAST R OF FIVE ISLANDS	021	028
	F			-	D J MACDOUGALL MINE	011	049
	FE	PB	CU	-	SAWPIT COVE	021	003
	AG	PB	ZN	-	GOLD DROP CLAIM	082	011
				-	BATHURST STA	031	069
				-	ART EKWI S	105	030
	FE	PB	CU	-	WOOD ISLAND	021	002
				-	INDEPENDENCE GOLD	104	001
				-	TROUT BR	011	057
	AG	F	ZN	-	STEWART QUARRY MAY ST	052	053
	F			-	JOHN CRAWFORD I	031	064
	F			-	ALASKA HWY MI 397	094	018
	PB	ZN		-	WOLF(BEAR)	094	022
				-	WARATAH CLAIM	103	004
	ZN			-	BERREA	031	111
	AG	F	ZN	-	MCINTYRE LOT 53	052	052
	TI			-	LITTLE DAM LAKE	031	122
	ZN			-	MACDONALD GR-KATHERINE CLM	093	013
				-	BARITE GOLD MINES LTD	104	005
	AG	CU		-	TB5038 CLAIM	052	089
	PB	CU		-	RENO CLS	082	039
				-	GRAND LAKE AREA	012	009
	AG	ZN	CU	-	PORT-ARTHUR SILVER 1	052	054
				-	ROMAINES BROOK	012	004
	CA			-	RYANS BROOK	011	062
	ZN	PB	AG	PRODUCER	FARO- NO1 AND 2	105	015
				PAST PRODUCER	LORRAIN(BAROID)	105	025
				-	MOORES PIT	011	050
	P			-	BLACKBURN MINE	031	121
	F			-	J A MACDOUGALL MINE	011	047
	PB	ZN		-	BISHOP CLS 5-6L	052	085
	SR			-	CORNEY BROOK(CAP ROUGE)	011	099
	ZN			PRODUCER	PARSON(HILLTOP SNOWDROP)	082	044
				PAST PRODUCER	PINK MINE	031	097
				-	EBY OR SCOTT CL	041	011
	CU			-	PHILLIPS CR	082	003
				-	N BURGESS	031	065
				-	MIDDLE STEWIACKE	011	003
	FE			-	LARRABEE PPTY	082	037
	F			-	WOODRUFFE MINE	031	082
	F			-	CRYDERMAN (RAVENA) PROP	042	003
	F			PAST PRODUCER	PETER CAMPBELL MINE	011	053
				-	FARRELL PPTY	031	063
				PRODUCER	YARROW BARITE MINE	041	015
	F	AG	ZN	PAST PRODUCER	PREMIER LANGMUIR MINE	042	006
				-	COLLIER COVE	001	072
				-	FOLEY MINE	031	100
	F			-	CAMPBELL MINE	011	046
				PRODUCER	BRISCO SALMON WAMINECA CLS	082	042
	F			PAST PRODUCER	JOHNSON, LOWER,UPPER VEINS	011	041
	F			-	IRONSIDE MINE	031	100

ELEMENTS				DEVELOPMENT CODE 1979	NAME	NTS NO	SEQUENCE NO
1	2	3	4				
	PB	ZN	CU	"	WALTON (MAGNET COVE)	021	013
	PB	ZN	AG	"	SOUTH MCKELLAR ISLAND	052	009
	ZN	AG	HG	"	RAMSEY MINE	031	086
				"	HODSON	011	025
	F	CU	MN	"	SCOTSVILLE DEPOSIT	011	054
				"	EUREKA(DUNCAN MINE)	021	019
				"	BROOKFIELD	011	005
	F			"	QUYON	031	182
	F			"	M MACMILLAN MINE	011	048
	AU	SR		"	LAKE SHORE GOLD MINE	042	004
BE	F	BI	W	OCCURRENCE	LOGJAM CREEK	104	021
	SN	F	AS	"	RUSH AND STANNITE GROUPS	052	100
	F	SN		"	LOW GRADE CLAIMS	104	016
	FLD	U	NB	PAST PRODUCER	CASEY HILL	031	091
	F	NB		"	CANADIAN BERYLLIUM	031	090
B	F	NB	TH	OCCURRENCE	SEAGULL CRE K	105	003
CA	F	SR		OCCURRENCE	CHEVERIE CLIFFS	021	009
	BA			PRODUCER	FRONTENAC QUARRY	031	001
CU	AU	AG	BA	OCCURRENCE	DALVENIE(BIG CHIEF)	104	012
	F			"	BEECH HILL	021	032
	FE	GYP		"	BARRA HEAD	011	020
	NI	F	MO	"	PARTRIDGE CROP LAKE AREA	063	002
	PB	ZN	W	"	CLEVELAND PROSPECT	021	043
	PB	ZN	F	"	ROK CAT	092	008
	BA			"	SPECTROAIRS HA CLAIMS	086	005
	BA			"	ALICE WILDA BETTY GREEN	082	004
	ZN	PB	BA	"	FOX GRP	103	009
	AU	BA		"	SENECA(ZENITH) DEP	092	002
	BA			"	TRI GROUP (1 TO 4)	086	007
	AU	BA		"	GEORGE COPPER GROUP	104	002
	BA	PB		"	LIN CLS LIARD R	095	006
CU	BA			OCCURRENCE	TOCHATWI BAY	075	005
	AG	BA	PB	"	COPPER KING IMPERIAL	082	035
	FE	PB	F	"	KAMINISTIKWIA R	052	039
	BA			"	CHENEY MINE	041	004
	PB	ZN	BA	"	TRI	094	007
	PB	ZN	BA	"	APEX(ROAD SHOWING)	093	010
	BA			"	PINK ISLAND	052	006
	F			"	THUBUN RIVER	085	003
	PB	F		"	BROOKBANK PPTY	042	002
	PB	BA		"	AILPORT PROSPECT(JOKER)	093	009
	ZN	PB	AG	PAST PRODUCER	LYNX MINE(WESTERN ML)	092	004
	ZN	PB	AG	"	BRITANNIA MINE BLUFF	092	007
	BA			"	BRUCE COPPER MINES	041	003
	ZN	AG	AU	"	TWIN J MINE	092	001
	PB	ZN	AG	"	MINERAL KING	082	034
C	F			OCCURRENCE	BOYER	031	137
FO	F			PAST PRODUCER	MACDONALD QUARRY	031	087
FE	MN	BA		DEVELOPED PROSPECT	GOSHEN MINE	021	010
	NB	U	BA	OCCURRENCE	IRON ISLAND	031	135
	ZN	PB	F	"	CLAREMONT GROUP	092	008
	CU	F		"	MARMORA	031	033
	BA	ZN		"	AUSTIN BROCK IRON MINE	021	047
	BA			PAST PRODUCER	MAYCOCK MINE	031	110
	BA			"	ACADIA IRON MINES	011	012
FLD	F	U		PAST PRODUCER	WOODCOX FELDSPAR MINE	031	088

ELEMENTS				DEVELOPMENT CODE 1979	NAME	NTS NO	SEQUENCE NO
1	2	3	4				
F				"	HAYPOOK POND VEIN	001	034
	BA	ZN	PB	"	LYBSTER TP (R64)	052	016
	MN			"	CHAPEAU ROUGE VEIN	001	015
	BA	PB	ZN	"	ALBERT BECK VEIN	001	014
				"	HARVEY CL NO. 18285	041	016
				"	LONG HARBOUR	001	073
	PB			"	ANSE-A-LA CAVE	022	001
	BA			"	CLAM POND	001	055
				"	NO	011	061
	BA			"	MCBEATH	031	041
				"	ROSS 2	031	125
				"	GRASSY GULCH VEIN	001	013
	BA	PB		"	LUNCH POND CLAIM	001	066
	FE			"	LEMAIRE TP	032	013
	B			"	DORSEY SHOWING	105	004
				"	HERRING COVE VEIN	001	029
				"	E OF WOLF LAKE	105	008
				"	QUICK WOOD VEIN	001	030
				"	TUCHIALIC BAY	013	001
	PB	ZN	CU	"	BLAKES BROOK VEINS	001	025
				"		082	047
	BA	PB	CU	"	LEAD VEIN	001	009
				"	HARBOUR ISL. (SE COAST)	001	069
				"	NEW BLACK DUCK VEIN	001	044
				"	STAR MINE	052	020
				"	HOOKEY BRANCH VEIN	001	039
	CU	PB	ZN	"	BEAUCHASTEL L	032	004
				"	BOXWEATER VEIN	001	043
				"	MADOC TP 3	031	046
				"	CANAL VEIN	001	024
				"	MALBAIE R CORBEAU CAPE	021	050
				"	TILT HILL	001	060
				"	WHEATON R S-FORK	105	001
	BA			"	SHARP PEAK	001	061
				OCCURRENCE	LAMBERT ISLAND	052	064
	BA			"	EASTERN LOOKOUT	001	087
	PB	ZN		"	R 135 WOODSIDE"S VEIN	052	022
	PB			"	CHURCH VEIN-MORRIS LEASES	001	038
	BA			"	WILLIAM REYNOLDS	031	038
				"	SISTERS BROOK	021	040
				"	LOCH ERNE	052	069
				"	SHATTER CLIFF	001	058
				"	MASBALA LAKE	064	001
	PB			"	SOUTHWEST MIRAMICHI RIVER	021	039
	BA	PB	CU	"	R 110 SILVER FALLS	052	014
				"	BERRY HILL	001	071
				"	HERRINGTON	031	023
				"	MCBEAN BROOK	021	036
				"	MONMOUTH TP	031	076
				"	ROCKY BROOK	021	041
	AG	AU	ZN	"	PRINCE"S MINE	052	005
				"	SOUTHWEST MIRAMICHI RIVER	021	038
				"	DWYER PPTY	031	082
				"	HARVEY STA	021	026
	PB	ZN	AG	"	BULL MOOSE CLAIM	085	002
	CU			"	MACGREGOR TP	052	059
	PB			"	PEERLESS MINE (R158)	052	024
				"	ROOKS	031	042
	B			"	WOLFE L AREA	105	009
				"	TRENKS PPTY	052	056
				"	LOCATION 124 NE WHITEFISHR	052	023
				"	MUNROE L GRANITE	064	002
				"	COLE MINE	031	120
	BA			"	FIVE MILE POINT	082	038
	BA			"	TP 87	042	012
				"	SNOW	094	014
				"	COBDEN	031	123
				"	WHITEMAN CR GREEN GABLES	082	029
	BA			"	SCRIPTURE"S VEIN	052	012
				"	ST UBALD PARISH	031	142
	WO	CU		"	ROCKSLIDE CR 2	115	003
				"	MADOC TP 4	031	030
				"	RICHARDSON	031	078
				"	HUNTINGDON	031	035

F	BA			DEVELOPED PROSPECT	FIRE(LIARD CROSSING)	094	019
	SA	U	CL	"	REXSPAR(BIRCH ISLAND)	082	051
				"	FLORENCE R G M	032	012
	W	PB	CU	"	FIDDLER YUKON MINE	105	005
	BA	PB		"	MEADOW WOODS VEIN	001	057
	BA			"	TEE(LIARD CROSSING)	094	021
	BA			"	TAM(LIARD CROSSING)	094	020
	ZN	PB		"	PAIPOONGE TP	052	041
	BA			"	CAMP CLIFF NICK BAR	094	017
	BA			"	CORAL(LIARD CROSSING)	094	018
	BA	PB		"	WALLEY VEIN	001	035
	AG			"	CROWN POINT MINE	052	015
				"	JOHNSTON	031	118
	U	TH		"	CALUMET URANIUM ML	031	128
F	BA			DEVELOPED PROSPECT	BARITE FAULT	001	011
	U			"	CLARK PPTY	031	084
				"	TAREFARE SHORE	001	009
	CA	BA		"	WALLBRIDGE PPTY	031	019
				"	MONTGOMERY PPTY	031	080
	U	TH		"	CARDIFF U MINE B-C ZONES	031	073
				OCCURRENCE	JOHANN BEETZ B	012	012
	U	TH	RE	"	VILLENEUVE MICA MINE	031	131
	ZN	CU		"	ALGOMA MINE	052	049
	BA			"	PLAIN	031	043
				"	ROCKSLIDE CR 1	115	002
				"	STROUDS HILL (OLD BALDY)	001	075
				"	EAGLET FLUORITE	093	002
	AG	ZN		"	HEWITSON QUARRY	052	051
				"	CAMPBELL TP	031	138
				"	ISLAND ROCK VEIN	001	028
				"	MNG LOC 277	052	008
	B	SN		"	PARTRIDGE CR	105	002
				"	LOWER CANOE LAKE	021	004
				"	AUMOND TP	031	139
				"	SALMON HOLE	001	051
	SN	NB	U	"	TIN ISLAND	052	099
	MO			"	BOURLAMAQUE TP	032	001
				"	RED ROBIN-MORRIS LEASES	001	032
	PB	CU		"	LOT 17 OSMUN VEIN	052	055
	P			"	CARDIFF TP	031	083
	PB	AG	AU	"	PLEASANT BAY	011	060
				"	LAWN ROAD V INS	001	041
	BA			"	ROCKY POND	001	059
	BA			"	STEWART MINE	031	026
	FL			"	QUEBEC STURGEON RIVER M L	032	014
	PB	ZN	AG	"	CHAMBERS COVE	001	003
				"	QUEBEC CITY	021	044
	PB	ZN		"	R 111 LYBSTER TP	052	018
				"	GILLIS BROOK	011	055
	BA	PB		"	BIG MEADOWS VEIN	001	056
	BA			"	ANCHOR DROGUE	001	062
	CU			"	LAWN	001	049
				"	COOK COPPER AND FLUORITE	032	003
	PB	ZN	AG	"	MINE COVE	001	036
				"	SHOAL COVE POND	001	010
				"	MADOC TP 5	031	022
	BA	PB		"	SHEARSTICK BROOK	001	063
				"	DEADMANS COVE VEIN	001	012
				"	LAWN HEAD	001	006
				"	FEMME HARBOUR	001	074
				"	SEATON ISLAND	052	095
	CU	PB		"	RED HEAD VEIN	001	002
	BA			"	WILLIAMS PPTY	031	005
				OCCURRENCE	TERRACE BAY	042	011
	SN			"	HUNKER GERMAINE CR PLACERS	116	001
	BA	CU	PB	"	SOUTHERN CROSS VEINS	001	037
				"	MOUNT MARGARET SPAR FLOAT	001	053
	U	TH		"	CALUMET CONTACT U MINES	031	127
				"	MOUNT ST HILAIRE	031	107
	BA	CU	PB	"	SALT COVE VEIN	001	007
				"	CRANBERRY BOG	001	046
	BA	PB	ZN	"	KNOBEL PT	052	066
				"	MOUNT ROYAL	031	099
	U	TH	CU	"	PONTEFRACT A-2 3	031	132
				"	GRAND BEACH	001	065
				"	JOHANN BEETZ A	012	011
				"	RYAN"S HILL VEIN	001	050
				"	SPICES COVE(LAWN HEAD)	001	005
				"	BIG SPRUCE LAKE	085	006
				"	WRIGHT	031	008
	PB			"	JONES PPTY	052	045
				"	LISTER"S MILLS	021	027
	PB	ZN	AG	"	ANDERSON VEIN	052	070
				"	STETSON-CUTLER QUARRY	021	015
	PB	ZN		"	R 115 TCHIATIN"S VEIN	052	019
	PB			OCCURRENCE	BAIE ST PAUL MOULIN R	021	049
	BA			"	BARRIE	031	067
				"	CAMERON TP	031	136
	AG	BA		"	FEDERAL MINE COPELAND VEIN	052	040
	P			"	ROSS 1	031	124
	BA			PAST PRODUCER	MACKAY-EVANS MINE	011	048
				"	DOCTORS POND VEINS	001	042
	BA			"	JOHNSON MINE	031	011
	BA			"	NOYES MINE	031	012
				"	BRODIE QUARRY	031	140
				"	BLACK DUCK MINE	001	045
				"	HOPE VEIN	001	020
	BA			"	HOWARD(HILL)	031	010
				"	BLOWOUT VEIN	001	018
				"	SCR. [illegible] VEIN	001	040
				"	SOUTH REYNOLDS	031	014
				"	MCILROY MINE	031	015
	P			"	NORTH STAR MINE	031	129
	BA	CU	PB	"	BLUEBEACH VEIN	001	023
	BA	SR	FL	"	PERRY LAKE	031	016
	BA			"	HILL PPTY	031	037
	BA			"	LITTLE SALT COVE BROOK	001	004
	PB	ZN	CU	"	GREBES NEST VEIN	001	031
				"	KILPATRICK (DETOMAC)	031	024
	BA			"	BAILEY MINE	031	029
	BA	CU	PB	"	TAREFARE MINE	001	021
	BA			"	LEE SENIOR	031	020
	CU	PB		"	HARES EARS VEIN	001	017
	U	TH	RE	"	MATTE ZONE	031	133
				"	IRON SPRINGS-W.EXTENSION M	001	016
	BA			"	LEE JUNIOR	031	036
				"	CROSS VEIN-TAREFARE MINE	001	019
	BA	U		"	ROCK CANDY FLUORITE MINE	082	009
				"	DIRECTOR MINE	001	022
				"	KEENE PPTY	031	027
	BA	PB	ZN	"	LORD AND LADY GULCH MINE	001	001
				"	BLUE BEACH NO 3	001	033
				"	NORTH REYNOLDS	031	025
	BA	ZN	SN	"	BLAKELEY MINE	031	013
				"	JONES	031	004
				"	PONTON	031	032
				"	MILLER	031	031
	BA	SR	FL	"	PERRY MINE	031	017
	BA			"	PALMATEER	031	003
				"	TRIPP FARM	031	079
	BA			"	ROGERS	031	021
				"	HERRINGTON SOUTH	031	007
	LI	MIC		"	OLD LEDUC MINE	031	126
HG	SB	AS	BA	PAST PRODUCER	PINCHI LAKE MINE MERCURY C	093	012
LI	F	BE		OCCURRENCE	GLEN (LUCY NO.1 CLAIMS)	052	094
	BE	F		"	EAGLE CLAIMS	052	101
	F	NB		PAST PRODUCER	OLD SILVER LEAF PGMT	052	097
MIC	F			PAST PRODUCER	DERRY TP	031	130
	P	F		"	WALLINGFORD MINE	031	116
MN	BA			DEVELOPED PROSPECT	STURGIS-FEUCHTWANGER MINES	021	011
	BA			OCCURRENCE	MANUELS-TOPSAIL AREA	001	070
	BA			"	MCCUISH(MOSELEY MINE)	011	034
	BA			"	LOWER BIRCH ISLAND	021	037
	BA			PAST PRODUCER	MACUMBER-DEEP HOLLOW MINES	021	008
	BA	F		"	MARKHAMVILLE MINE	021	022
	BA			"	EAST MOUNTAIN	011	008

ELEMENTS 1	2	3	4	DEVELOPMENT CODE 1979	NAME	NTS NO	SEQUENCE NO
MO	U	F		DEVELOPED PROSPECT	SILVER HOARD CLAIM	082	016
	BE	LI	F	OCCURRENCE	GOYETTE-SUP PROPERTY	032	010
	CU	F	BA	"	BELLE ISLAND	001	079
	F			"	LACORNE TP	032	008
	CU	FL	F	"	BIG BIGHT	013	003
	CU	F		"	WEWA(RAM)	082	010
	U	F		PAST PRODUCER	MOSS MINE	031	113
	BF	F		"	BLOCK F	032	009
	F	BI	BE	"	LACORNE MINE	032	007
NB	U	BA		DEVELOPED PROSPECT	NEWMAN DEPOSIT	031	134
	BA			OCCURRENCE	FIRESAND R CARBONATITE	041	012
	MO	U	BA	PRODUCER	ST HONORE	022	004
	TA	BA	SR	PAST PRODUCER	ST LAWRENCE COLUMBIUM MINE	031	098
	TH	U	F	"	BASIN DEPOSIT	031	077
PB	AG	AS		DEVELOPED PROSPECT	SILVER BASIN CLAIM	105	032
	BA			"	MURPHY-HICKEY PPTY	031	051
	ZN	AG	BA	"	GAY"S RIVER PB-ZN DEPOSIT	011	002
	AG	BA		"	YORNOC DAVE (40CLS)	082	031
				OCCURRENCE	LOCH LOMOND(L UIST SETT)	011	031
	ZN	F		"	QUEENS BROCK FLUORITE	021	021
	ZN	F		"	SNUFF CHANNEL (S.OF)	085	001
	ZN	AG	BA	"	BURN(1-20)	094	005
	ZN	BA		"	PEMBROKE(GLENBERVIE)	011	006
	ZN	F	BA	"	BRANDY BROOK	022	006
PB	F			OCCURRENCE	OKIKODASIK R MOUTH	032	011
	ZN	BA	F	"	FRYE ISLAND	021	006
	BA	ZN		"	MURPHY-HICKEY	031	052
	MO	ZN		"	EMERALD MINE	082	085
	ZN	BA	AG	"	BONANZA (PRINCE GEORGE)	093	004
	ZN	AG	AG	"	FAIN(1-10)	094	006
	BA			"	JAMES MURPHY	031	050
	ZN	AG	BA	"	SANTACK	052	077
	CU	BA	AG	"	RUBY CLAIM(SHUNIAH MINE)	104	008
	BA	ZN		"	KEMERER PPTY	052	078
	BA			"	BURRIDGE RD	031	055
	ZN	BA	CU	"	LITTLE NARROWS JUBILEE	011	037
	ZN	AG	BA	"	ENGINEER CLAIM	103	003
	AG	BA	CU	"	MUSKATEER GROUP	103	016
	ZN	BA	CU	"	LYALL AND BEIDELMAN PROP.	022	005
	CU	F		"	STAG BAY	013	002
	ZN	BA		"	CAMPOBELLO ISLAND	021	005
	ZN	BA		"	QUARTZ LAKE	095	001
	ZN	BA	CU	"	MAZOKAMA BAY PROS.TB4588SE	052	090
	ZN	PY	BA	"	WEBER GROUP	094	002
	ZN	BA		"	HOMEBUSH CLMS	103	011
	ZN	F		"	PARASSEUX RAPIDS VEIN	052	043
	ZN	CU	AG	"	SF PROPERTY	104	011
	ZN	FL	F	"	WIGWAM GROUP	082	041
	ZN	BA	CU	"	RIVER JORDAN DEPOSIT	082	048
	BA			"	ST CLAIR PPTY	052	082
	BA			"	MURPHY MINE	031	059
	AG	BA	ZN	"	RED TOP GROUP	104	003
	BA	ZN		"	CAMPBELL SHOWING	031	096
	ZN	BA	CU	"	DETROIT-ALGOMA MINE	052	075
	AG	F	BA	"	SILVER L VEINS	052	068
	ZN	AG	CU	"	EARLY BIRD CLAIM	082	013
	CU	BA	F	"	PONA PROPERTY	093	006
	BA	ZN	AG	"	BLENDE LAKE VEIN	052	067
	ZN	BA	F	"	GORDON CL 6038	052	091
	ZN	AG	BA	"	MALLARD LAKE PROJ	032	085
	ZN	BA	CU	"	ROTI POINT	001	089
	ZN	BA		"	CASEY CAMP	103	007
	BA			"	METHUEN LEAD VEIN	031	049
	ZN	BA		"	LEBEL PPTY	052	086
	ZN	BA		"	THUNDER BAY PB-ZN PPTY	052	087
	ZN	AG	AG	"	SHENANGO-RAINBOW CLS	082	001
	ZN	CU	BA	PAST PRODUCER	STIRLING(MINDAMAR) MINE	011	024
	ZN	AG	BA	"	SILVER GIANT MINE	082	043
	ZN	BA		"	SMITHFIELD PB-ZN MINE	011	004
	ZN	AG	AU	"	SILVER CLIFF MINE	001	068

ELEMENTS 1	2	3	4	DEVELOPMENT CODE 1979	NAME	NTS NO	SEQUENCE NO
SB	PB	AG	ZN	OCCURRENCE	CARIBOU-CHIEFTAIN HILLS	105	087
SI	BA			PAST PRODUCER	LYNDHURST QUARTZ MINE	031	039
SN	F			OCCURRENCE	SILVER DIAMOND	104	020
	F	BE	NB	"	SHATFORD L(E-END)	052	090
SR	BA			DEVELOPED PROSPECT	RONAN DEPOSIT	012	005
	BA			OCCURRENCE	GILLAMS COVE	012	006
				"	ST HELEN ISLAND	031	100
	BA	PB		"	BECKWITH(DICKSON BROOK)	011	035
				"	AMHERSTBURG	040	001
				"	WAHL PROSPECT	052	096
				"	FEATHERTON SHOWING	012	002
				"	ST MARY'S	040	002
				"	HAWKSBURY	031	112
	BA			"	FRAZER DUNTILE QUARRY	031	093
	BA			"	MORDEN VERONA DEP	031	036
	BA	PB	AG	"	GILLAMS COVE (W. OF)	012	007
				"	CREDIT FORKS	030	001
				"	NEPEAN TP	031	092
	BA	BA		"	BUELL(LANSDOWNE)	031	040
	AU	CU		"	ISL. IN THIRD CRANBERRY L.	063	001
				"	MANITOUWANING	041	001
SR				OCCURRENCE	CAPE ROBERT	041	002
				"	FRENCHVALE	011	039
	PB	ZN	CU	PAST PRODUCER	KAISER CELESTITE	011	028
				"	REAR BLACK RIVER	011	021
	PB			"	FRONTENAC LEAD MINE	031	009
	BA			"	WILDER(CALABOGIE)	031	089
U	F	TH		DEVELOPED PROSPECT	CARDIFF U MINE A E ZONES	031	075
	NB	F		"	BUGABOO VOWELL FORSTER CPS	082	040
	F			"	MANNERS SUTTON	021	025
	AG	BA	F	"	COBALT GRP ELDORADO MINE	086	003
	CU	F		"	REX GROUP (ABCDE STEVENS)	075	004
	BA	CU		"	ACHOOK IS	086	004
	F			"	YORK MILLS	021	024
	SR			"	FARADAY U MINE	031	074
W	BE	SN	F	OCCURRENCE	BLUE LIGHT	104	019
	MO	SN	F	"	BURNT HILL MINE	021	042
	CU			PRODUCER	CANADA TUNGSTEN MINE	105	012
ZN	PB	BA		DEVELOPED PROSPECT	VANGORDA CR PPTY	105	014
	PB	CU	BA	"	CUPRA MINE	021	029
	PB	BA	F	"	IT IN TO(RUDDOCK CR)	052	052
	F	SN	FL	"	MT PLEASANT MINE	021	018
	PB	AG	BA	"	SWIM LAKE PPTY	105	013
	PB	F	FL	"	BIG BEAR VEIN	052	035
	PB	BA		"	JASON CLAIMS	105	022
	PB	FL	F	OCCURRENCE	LOT 1A MACGREGOR TP	052	061
	PB	BA		"	CTV CBC HOPE DODO	094	009
	PY	PB	BA	"	GORDON CLS	094	001
	PB	BA		"	FOX GROUP(OAK R)	103	010
	PB	BA	F	"	EGG FOO	094	008
	PB	AG	AU	"	NINE MILE BROOK	021	045
	BA	PB		"	DAVIES CLAIMS	094	003
	PB	CU	AG	"	PRICE PPTY(WESTERN ML)	092	003
	AG	CU	BA	"	PANVILLE GRP (BIG BULL)	104	013
	PB	BA		"	OZONE SIDING LEWIS SEYLEP	052	092
	BA	CU		"	GUNN CLAIMS	105	017
	PB	BA	F	"	OZONE SIDING MCL TB4588	052	093
	PB	BA	AG	"	VERNON, DONNA	093	015
	PB	AG	BA	"	ZINC GROUP(PM)	105	010
	PB	BA	AG	"	CLIMAX GRP	103	017
	PB	CU	F	"	SUNDAY CLAIM	082	050
	PB	BA		"	POLARIS MINE	068	001

	AG	ZN	F	"	THUNDERBAY MINE (58)	052	058
	ZN	CU	BA	"	LA MANCHE MINE	001	085
	ZN	BA		"	LEADVILLE GRP.(LUCKY TODD)	092	010
PB	CU	AG	AU	PAST PRODUCER	ENTERPRISE MINE	052	074
	ZN	AG	AU	"	SILVER TIP	104	004
	ZN	BA	F	"	KINGDON CR GALETTA PB MINE	031	095
	ZN	AG	CU	"	JARDUN MINE	041	005
	ZN	BA		"	UNION CR LEAD MINE	031	061
	ZN	FL	CU	"	HIGHLANDER(HIGHLAND MINE)	082	017
	ZN	AG	F	"	OGEMA MINE	052	080
	ZN	BA		"	DORION MINE	052	084
	ZN	AG	F	"	GALENA FARM MINE CURRIE GR	082	027
PYR	ZN	PB	CU	PRODUCER	BRUNSWICK NO.6-SULFIDE DEP	021	046
PY	ZN	PB	CU	PAST PRODUCER	MOULTON HILL-ALDERMAC MINE	021	016
P	F			OCCURRENCE	SICOTTE TP	031	141
	F			"	CANADA RADIUM	031	072
	MI	F		PAST PRODUCER	RAINVILLE(CUGAS) MINE	031	115

	PB	AG	BA	PAST PRODUCER	MIDNIGHT (CHISHOLM) CLAIM	093	009
	PB	CU	BA	PRODUCER	BUCHANS MINE-ZONE E	012	010
ZN	CU	PB	AU	PAST PRODUCER	TULSEQUAH CHIEF-BIG BULL	104	014
	PB	AG	BA	"	BLACK HILL EXCELSIOR GRP	103	018
	BA	CU	PB	"	BRITANNIA MINE JANE	092	026
	BA	CU	PB	"	BRITANNIA MINE FAIRVIEW	092	089
ZR	SR			OCCURRENCE	ST MICHEL SILL	031	119

Table 35. Major elements and development code of Canadian strontium deposits

ELEMENTS						DEVELOPMENT CODE 1979	NAME	NTS NO	SEQUENCE NO
1	2	3	4	5	6				
ZR	SR					OCCURRENCE	ST MICHEL SILL	031	119
U	SR					PAST PRODUCER	FARADAY U MINE	031	074
SR						PAST PRODUCER	REAR BLACK RIVER	011	021
-						OCCURRENCE	FRENCHVALE	011	039
-	BA					PAST PRODUCER	WILDER(CALABOGIE)	031	089
-						OCCURRENCE	MANITOUWANING	041	001
-	BA					-	FRAZER DUNTILE QUARRY	031	093
-	BA					-	MORDEN VERONA DEP	031	036
-	AU	CU				-	ISL. IN THIRD CRANBERRY L.	063	001
-	BA					-	BUELL(LANSDOWNE)	031	040
-						-	NEPEAN TP	031	092
-						-	CAPE ROBERT	041	002
-						-	HAWKSBURY	031	112
-						-	AMHERSTBURG	040	001
-	PB	ZN	CU	AG	BA	PAST PRODUCER	KAISER CELESTITE	011	028
-	BA	PB	AG			OCCURRENCE	GILLAMS COVE (W. OF)	012	007
-	BA	PB				-	BECKWITH(DICKSON BROOK)	011	035
-						-	HEATHERTON SHOWING	012	002
-						-	ST HELEN ISLAND	031	100
-	BA					-	GILLAMS COVE	012	006
-	BA					DEVELOPED PROSPECT	RONAN DEPOSIT	012	005
-						OCCURRENCE	ST MARY'S	040	002
-						-	CREDIT FORKS	030	001
-	PB					PAST PRODUCER	FRONTENAC LEAD MINE	031	009
-						OCCURRENCE	WAHL PROSPECT	052	096
NB	TA	BA	SR			PAST PRODUCER	ST LAWRENCE COLUMBIUM MINE	031	098
F	BA	ZN	SR	AG		PAST PRODUCER	BLAKELEY MINE	031	013
-	BA	SR	FE			-	PERRY LAKE	031	016
-	SR	U	CE	LA	Y	DEVELOPED PROSPECT	REXSPAR(BIRCH ISLAND)	082	051
-	BA	SR	FE			PAST PRODUCER	PERRY MINE	031	017
CU	PB	ZN	BA	SR		OCCURRENCE	APEX(ROAD SHOWING)	093	010
CA	F	SR				OCCURRENCE	CHEVERIE CLIFFS	021	009
BA	SR					PAST PRODUCER	CORNEY BROOK(CAP ROUGE)	011	059
-	AU	SR				-	LAKE SHORE GOLD MINE	042	004
-	SR					OCCURRENCE	BYERS CREEK	011	014
BA	SR					DEVELOPED PROSPECT	DORCHESTER(DORBECK)	021	031
AU	BA	SR				OCCURRENCE	HORSEFLY PLACER	093	001

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